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# PCB Disposal by Thermal Destruction

(U.S.) Environmental Protection Agency
Dallas, TX

Jun 81

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# PCB DISPOSAL
# BY
# THERMAL DESTRUCTION

Compilation of Data and Information for the Approval of
Rollins Environmental Services, Deer Park, Texas
and
Energy Systems Company (ENSCO), El Dorado, Arkansas for
Disposal of Polychlorinated Biphenyls (PCBs)

February 1982

Final Report

Environmental Protection Agency
Region 6
Dallas, Texas

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A report on the sampling, analysis, and consideration of risks and benefits associated with the incineration of polychlorinated biphenyls (PCBs) at two commercial facilities in Deer Park, Texas and El Dorado, Arkansas. Included are a summary, PCB incineration test reports, polychlorinated dibenzo-p-dioxin (PCDD) and polychlorinated dibenzofuran (PCDF) emission sampling reports, a PCDD and PCDF analytical chemistry report, air dispersion modeling results, an analysis of risks and benefits, and letters and conditions of approval.

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# INCINERATION OF PCBs - A SUMMARY OF EPA-REGION 6 APPROVAL ACTIONS

U.S. EPA, Region 6, Dallas, Texas

BACKGROUND - In response to mounting evidence that polychlorinated biphenyls (PCBs) were a high risk chronic toxicant, Congress, in 1976, banned the manufacture of these compounds. Final regulations[1] published on May 31, 1979, prohibited the manufacture, distribution, and use of PCBs after July 2, 1979, and detailed specific storage and disposal requirements. All materials with PCB concentrations greater than 500 ppm must be incinerated under EPA prescribed conditions (See Table 1). A large portion of the electrical industry's PCBs fall into this category. Other acceptable disposal methods for lower PCB concentrations (50-500 ppm) include landfilling and incineration in high efficiency boilers. In the regulations for PCB incinerators, there is a provision which allows the Regional Administrator to require a trial burn to ensure that the operational requirements of the incinerator are met. This report summarizes the approval actions completed by EPA-Region 6 for two PCB incinerators.

CHRONOLOGY OF FIRST TRIAL BURNS - EPA-Region 6 received applications for PCB incineration from Energy Systems Company (ENSCO) at El Dorado, Arkansas, on March 8, 1978, and from Rollins Environmental Services at

Deer Park, Texas, on April 6, 1978. The first PCB trial burns were conducted at ENSCO in October 1979, and at Rollins in November 1979. While both facilities demonstrated compliance with PCB regulations for temperature, destruction efficiency, residence time, excess oxygen, and acceptable carbon monoxide concentrations, laboratory results revealed the possibility that very low levels of two toxic organic compounds were present in some of the stack samples. These compounds were tetrachlorodibenzo-p-dioxins (TCDD) and tetrachlorodibenzo-furans (TCDF). At this point Region 6 determined that additional tests were warranted at ENSCO and Rollins to determine whether dioxins and furans were actually being emitted during PCB combustion and the quantities and sources of these compounds, i.e. waste auxiliary fuels, PCBs. Both facilities used waste fuels during PCB incineration to achieve their operating temperatures. EPA paid for the sample collection, sample preparation, analytical analyses, and the oil for these retests.

## TABLE 1

## PCB INCINERATOR REQUIREMENTS

| | |
|---|---|
| Destruction Efficiency | 99.9999% |
| Temperature | 1150°C |
| Dwell Time | 2 seconds |
| Excess Oxygen | 3% |
| CO | < 100 ppm |
| HCl Removal | 99% |
| Particulates | State Permit |
| PCB Feed Rate | Test Burn |

CHRONOLOGY OF SECOND TRIAL BURNS - The second trial burn plan was developed jointly by Region 6 and the Office of Pesticides and Toxic Substances with agreement by the applicants. The plan included three days of sampling during the incineration of a variety of fuels. Incineration on the first day was with the facility's normal waste fuel and no PCBs. The second day of incineration was with normal waste fuel and PCBs, while the third day was with PCBs and virgin fuel oil. The sampling was conducted by an independent testing firm using methods and procedures prescribed by EPA. EPA was present during all tests. The retests were performed in August 1980.

SAMPLING METHODS AND ANALYSIS FOR DIOXINS AND FURANS - The sampling of stack emissions for dioxins and furans was with a modified EPA Method 5 Train[2]. The train incorporated two resin cartridges, XAD-2 and florisil, to adsorb the volatile organics (Figure 1). The resin cartridges were located downstream from the heated probe and between the third and fourth impingers. The sampling train was designed to collect both particulates and organic compounds in the stack gas. Two resins were used to insure adsorption of organics which may have passed through the first resin. Resin cartridges and impingers were water jacketed to maintain a temperature below 70°F. The effect of ultraviolet light on photosensitive organic compounds was minimized by covering the train with aluminum foil and opaque plastic.

The stack gases were sampled isokinetically for a period of four hours during each of the three days of incineration. After being transported to the laboratory, stack samples were extracted with an appropriate solvent and analyzed using capillary column gas chromotography and high resolution mass spectrometry[3]. For dioxins and furans, an added quality control technique was used. The samples were spiked with a chlorine-37 labeled dioxin and furan which allowed the analyst to determine the extraction efficiency of each sample.

RESULTS OF TRIAL BURNS - The results of both trial burns at ENSCO and Rollins are provided in Tables 2 and 3. PCBs were not analyzed from stack samples from the second trial burn since no PCBs were detected during the first burn. The 1980 data are the results from the second day when the auxiliary chemical waste fuel was being burned with PCBs. When only chemical wastes were being incinerated, dioxins and furans were also detected in the stack samples (Table 4). During day one, both incinerators were operating below 1200°C.

PREDICTION OF AMBIENT AIR CONCENTRATIONS - The dioxin and furan emission data from the second test were used to predict maximum ground level concentrations. Calculation of the dioxins/furans was by the use of the RAM[4] air dispersion model which is applicable to level terrain. The CRSTER[5] model was used for the El Dorado facility, where the terrain is not level. The model simulates plume dispersion behavior as it travels downwind from the stack by utilizing parameters such as temperature and velocity of stack gases, stack height, wind speed and direction, and mixing height. Maximum concentrations for the dioxins/furans, as predicted by the model, were in the order of $10^{-14}$ to $10^{-15}$ grams/cubic meter.

FIGURE 1 STACK SAMPLING TRAIN

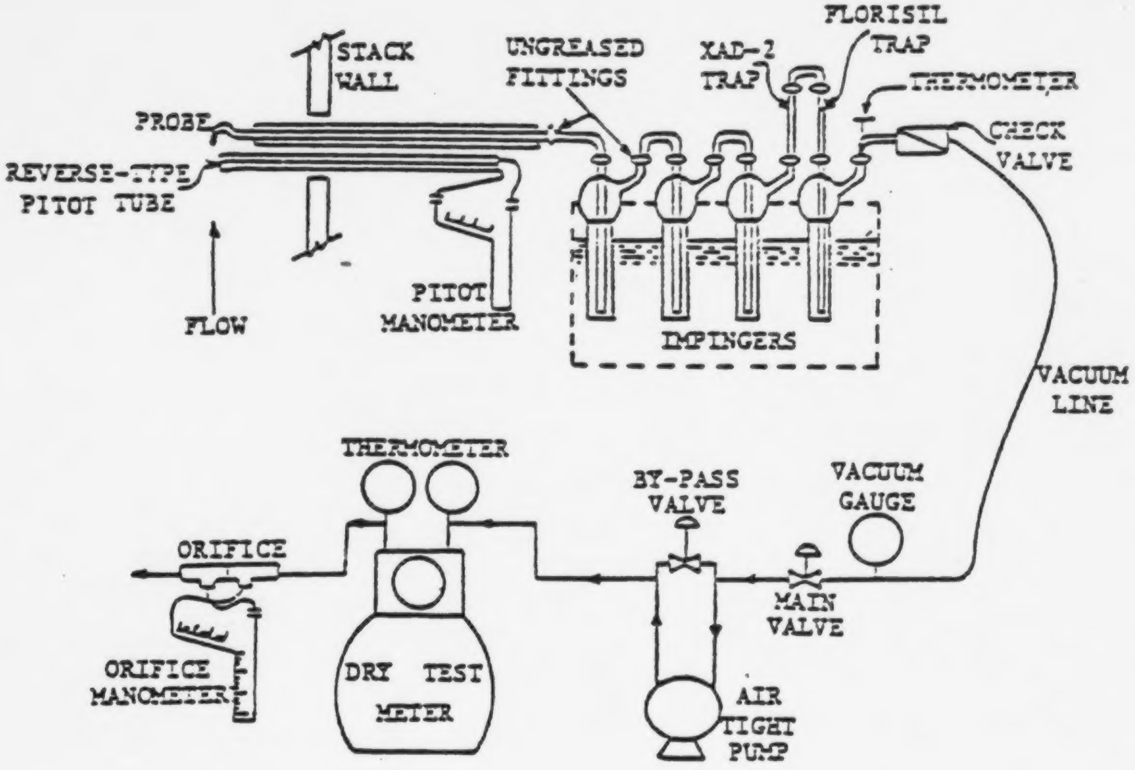

TABLE 2

ENSCO, El Dorado, Arkansas

Results of Trial Burns

| | Oct. 1979 | Aug. 1980 |
|---|---|---|
| PCB Feed Rate, lb/hr | 636 | 722 |
| Temperature $^{o}C$ (avg) | 1254 | 1224 |
| CO, ppm (max) | 10 | 7 |
| Excess $O_2$, % | 13.4 | 9.5 |
| $CO_2$, % | --- | --- |
| Particulates, lb/hr | 149 | 8 |
| HCl Removal eff, % | 98.9 | 99.8 |
| PCB Destruction eff, % | 99.99998 | no PCB analysis |
| Combustion eff, % | 99.98 | 99.99 |
| *Dioxin, ng/dscf | not analyzed | 0.005 |
| *Furan, ng/dscf | not detected** | 0.060 |

*ng/dscf = nanogram per dry standard cubic foot.

**detection limit of 1980 analysis was 1000 times greater than 1979 detection limit.

## TABLE 3

### Rollins Environmental Services, Deer Park, Texas

### Results of Trial Burns

| | Nov. 1979 | Aug. 1980 |
|---|---|---|
| PCB Feed Rate, lb/hr | 2438 | 2502 |
| Temperature, $^{o}$C (avg) | 1185 | 1175 |
| CO, ppm (max) | 11 | 38 |
| Excess $O_2$, % (min) | 8.9 | 9.8 |
| $CO_2$, % | 9 | 8.1 |
| Particulates, lb/hr | 39 | 24 |
| HCl Removal eff, % | 98.4 | 99.9 |
| PCB Destruction eff, % | 99.99999 | no PCB analysis |
| Combustion eff, % | 99.98 | 99.95 |
| *Dioxin, ng/dscf | Not Analyzed | 0.018 |
| *Furan, ng/dscf | Not Detected** | 0.281 |

*ng/dscf = nanogram per dry standard cubic foot.

**detection limit of 1980 analysis was 1000 times greater than 1979 detection limit.

TABLE 4

RESULTS OF TCDD AND TCDF ANALYSES FROM SECOND TRIAL BURN

| ROLLINS | Total TCDD | Total TCDF |
|---|---|---|
| Day 1 (chemical waste) | 6.94 ng | 13.5 ng |
| Day 2 (chemical waste and PCBs) | 1.42 ng | 23.0 ng |
| Day 3 (fuel oil and PCBs) | Not Detected | 2.0 ng. |
| **ENSCO** | | |
| Day 1 (chemical waste) | 0.26 ng* | 2.0 ng |
| Day 2 (chemical waste and PCBs) | 0.48 ng | 6.0 ng |
| Day 3 (fuel oil and PCBs) | Not Detected | Not Detected |

*Excludes Impinger Water

UPPER LIMIT RISK ASSESSMENT - With the verification that dioxins and furans would be present in the stack gases during PCB incineration, Region 6 decided to develop, with the assistance of EPA's Carcinogen Assessment Group, an upper limit risk assessment to determine whether these toxic compounds would pose a significant health risk to area residents.

ASSUMPTIONS - Realizing that there was limited toxicological evidence for all but the 2, 3, 7, 8 isomer of TCDD and even less for the furans, EPA-Region 6 developed the risk assessment as a "worst case" by making very conservative assumptions to replace the missing toxicological information. The key "worst case" assumptions were as follows:

1. All TCDD and TCDF were assumed to exhibit the same degree of toxicity and carcinogenicity as the 2, 3, 7, 8 isomer of TCDD

2. The toxicity and carcinogenicity of 2, 3, 7, 8 TCDF equals that of 2, 3, 7, 8 TCDD

3. The sensitivity of humans to the health effects of these materials equals that of the most sensitive species observed in lab studies

4. For 2, 3, 7, 8 TCDD, there is no threshold level below which carcinogenic risk is zero

5. The duration of exposure to this material will be a 70 year average lifetime period

6. The frequency of exposure is 24 hours per day, 7 days per week for 70 years

7. The intensity of exposure is calculated from ambient concentrations of TCDD and TCDF which are predicted by a computerized air dispersion model from the actually measured stack emissions

8. The total population within the affected area is exposed to the highest ambient concentration of TCDD and TCDF predicted by the model

9. All human exposure will be through inhaling tiny airborne particles to which TCDD and TCDF adhere

10. The typical exposed person:
    a. breathes 20 $m^3$/day
    b. ingests and retains 100% of the particulates inhaled
    c. absorbs 100% of the TCDD and TCDF
    d. has an average body weight of 60 kg.

EXPOSURE ESTIMATES - The intensity of exposure was predicted by the previously discussed air computer modeling. The population exposed to these concentrations were estimated in the following way:

> Rollins: The population within a three-mile radius of the Rollins stack included the total population of Deer Park, Texas, and an estimated 1/3 of the population of the town of Deepwater. Also included in the population estimate were an additional 300 employees from nearby industries even though these people are only subject to an eight-hour exposure. The 1980 population records were furnished by the Houston-Galveston Area Council of Governments. The computer modeling showed the maximum concentration of TCDD and TCDF to occur at a point 1 1/2 miles from the stack with an estimated 25,000 people within the 1 1/2 mile radius circle.
>
> ENSCO: The total metropolitan population of El Dorado, plus the suburban and rural population of most of the county, were assumed to be exposed. These 1980 figures came from documents used by EPA for water quality planning in the El Dorado area. The estimate is 50,000 people, with 24,000 residing in the area of maximum concentration (1.2 km).

The total estimated exposed population is assumed to be located and subject to the highest predicted ambient concentrations of TCDD/TCDF.

CALCULATION OF PREDICTED RISK - EPA's Carcinogen Assessment Group has prepared for the Office of Air Quality Planning and Standards a Risk Assessment Document[6] which summarizes data on TCDD. This document estimates that the unit risk factor associated with breathing (70 year exposure) air containing one nanogram of 2, 3, 7, 8-TCDD/$m^3$ is 0.091, i.e., 91 increased cases of cancer per 1000 people. This factor was used with the predicted air concentrations at the two incinerators to arrive at a site-specific upper limit of risk.

The resulting individual risk for ENSCO was found to be $3.9 \times 10^{-7}$,* or less than one increase case of cancer per 2,500,000 exposed persons. For the Rollins facility, the value was found to be $1.8 \times 10^{-5}$*; or less than one increased case of cancer in 50,000 exposed persons. These numbers do not represent an estimate of the actual individual risk from operation of the incinerators, but are an estimate of the upper level of risk possible if all the worst case assumptions occurred. Such an occurrence is virtually not possible.

PCB INCINERATION APPROVAL CONDITIONS - The PCB Regulations stipulate the performance requirements which must be met prior to the granting of approval by the Regional Administrator (40 CFR Part 761). Additionally, the regulations allow the Regional Administrator to include any other requirements which are necessary to ensure that the operation of the incinerator does not present an unreasonable risk of injury to health or the environment from PCBs. The following PCB incineration approval conditions outline specific conditions which must be met to remain an approved PCB disposal facility.

---

*Based on analyzed dioxin/furan levels where detected, plus levels of detection where not detected. This is an additional conservative consideration.

To ensure combustion efficiency greater than 99.9%, the approved facility must operate above 1100°C, with excess oxygen greater than 3% and carbon monoxide (CO) less than 10 times the $CO_2$ level. If at any time during PCB incineration the combustion efficiency drops below 99.9%, or the temperature drops below the minimum specified, an automatic cutoff mechanism stops the flow of PCBs to the incinerator.

The incineration of chlorinated compounds produces chlorine in the combustion gases; 99% of this chlorine must be removed by the wet scrubber to comply with the PCB approval conditions. Particulate emissions from the stack of the facility must meet the State's particulate emission permit limit. Annual retesting may be required by EPA to ensure continued compliance with particulate and chlorine limits.

Other approval conditions include requirements for handling, storage, marking, and record keeping. All PCBs received at the facility must be recorded as to quantity, date received, and from whom the PCBs were received. Also, the facility must record the date and quantity of PCBs incinerated. These records and the incinerator operation will be monitored regularly by EPA and by an independent contractor who will inspect the facility at random times.

In addition to compliance with the PCB requirements, the incineration facilities must meet all applicable State, local, and Federal regulations during PCB incineration.

## References

1. Federal Register, 44: 31514, May 31, 1979, (40 CFR Part 761).

2. Method 5 - Determination of Particulate Emissions from Stationaly Sources, 40 CFR 60,344, Appendix A.

3. Tiernan, T.O. *et al*, Determination of Polychlorinated Dibenzo-p-Dioxins (PCDDs), Dibenzofurans (PCDFs), and Biphenyls (PCBs) in Stack Effluents and Other Samples Resulting from Assessments of PCB Incineration Tests at Rollins Environmental Services, Deer Park, Texas and Energy Systems Company (ENSCO), El Dorado, Arkansas. U.S. EPA Cooperative Agreement #CR806846.

4. User's Guide for RAM, November 1978, EPA-600/8-78-016A.

5. Users Manual for Single-Source (CRSTER) Model, July 1977, EPA-450/2-77-013.

6. U.S. EPA Carcinogen Assessment Group, Office of Health and Environmental Assessment, Office of Research and Development. "Method for Determining the Unit Risk Estimates for Air Pollutants." July 1980.

# Division 1

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# Disposal of Polychlorinated Biphenyls (PCBs) and PCB-Contaminated Materials
## Volume 4: Test Incineration of Electrical Capacitors Containing PCBs

FP-1207, Volume 4
Research Project 1263-2

Final Report, September 1980
Work Completed, May 1980

Prepared by

ACUREX CORPORATION
Energy and Environmental Division
485 Clyde Avenue
Mountain View, California 94042

Project Manager
J. Steiner

Principal Investigators
N. W. Flynn
C. D. Wolbach

Prepared for

Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, California 94304

EPRI Project Manager
R. Y. Komai

Water Quality Control and Heat Rejection Program
Coal Combustion Systems Division

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**Prepared by**
**Acurex Corporation**
**Mountain View, California**

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## ABSTRACT

This report presents the results of a trial burn conducted at the Energy Systems Company (ENSCO) located in El Dorado, Arkansas. The purpose of the trial burn was to determine whether liquid PCBs and shredded electronic capacitors could be incinerated in accordance with the recent Environmental Protection Agency (EPA) rules and regulations published in the Federal Register (40 CFR Part 761, Vol. 44, No. 106, pp. 31513-31568, May 31, 1979).

The report contains a brief overview of published literature on PCB incineration, a description of the ENSCO facility, a detailed discussion of the sampling and analysis procedures and a summary of the results obtained from the trial burn. The raw data and sample calculations used to obtain the results are contained in appendixes at the end of the report.

Based on the results of this trial burn, PCBs were not detected in the stack effluent, the scrubber liquor effluent or the recycled scrubber liquor from the sludge lagoon. PCBs were detected in the ash effluent from the rotary kiln and were less than 50 ppm, the lower limit at which PCBs are regulated by the EPA. A discussion is given of problems associated with the EPA perchlorination procedure for analyzing PCBs.

## EPRI PERSPECTIVE

### PROJECT DESCRIPTION

This final report is the succeeding volume to the set of three volumes previously published on disposal of polychlorinated biphenyls (PCBs) and PCB-contaminated materials. This project (RP1263-2) is one of a series aimed at the safe disposal of utility-generated wastes--specifically in this case, the sampling and analysis during PCB incineration. Jointly funded under EPRI's Interdepartmental Solid-Waste Disposal Program, the contractor presents the analytic considerations, procedures, and results of the Energy Systems Company (ENSCO) PCB test burn in El Dorado, Arkansas, in October 1979. The electric power-generating industry's interest in this project stems from its ownership of the majority of existing PCBs in this country and its constraint by federal regulations to a limited number of disposal options.

### PROJECT OBJECTIVE

The overall objective of this study was to participate in and to document sampling and analysis procedures utilized in the certification test burn of PCBs. This is essentially a case study of an EPA-required test burn for a commercial PCB incinerator.

### PROJECT RESULTS

The test found destruction of the PCBs to be highly efficient. Samples taken from the stack, the scrubber, and the ash were analyzed for PCBs. PCBs were only confirmed in the ash, but at levels below the federally regulated amount of 50 PPM.

An analytic problem, which arose and should be kept in mind during PCB analysis, stemmed from the perchlorination process. The principle is to convert whatever chlorinated biphenyls are present into decachlorobiphenyl (converting the 209 possible PCBs into a single compound). There are a number of problems arising from this technique. Biphenyl (a non-PCB, nonregulated substance) is converted to a PCB and counted as such. The mass of PCBs reported may be significantly greater due to the higher molecular weight when chlorines are substituted onto the molecule, i.e., the molecular weight may be doubled. False positives may be obtained and, without confirmatory tests, one could erroneously report the presence of PCB.

The analytic work by Acurex included the occurrence of false positives. Because of the sensitivity of this incineration test, it was decided that gas chromatography-mass spectrometry would be used for confirmation of PCBs. None were found in the unperchlorinated stack gas samples or the scrubber water.

It is recommended that the perchlorination method of PCB analysis only be used as a screening technique, and that positive results be confirmed on the unperchlorinated sample. There is a danger of reporting PCBs even if none are present, unless a second technique is used to verify the PCB level obtained by the perchlorination analysis procedure.

The incineration process proved to be an effective and efficient way of destroying PCBs. It will be a useful option for PCB disposal by utilities.

Ralph Y. Komai, Project Manager
Coal Combustion Systems Division

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## SUMMARY

The first commercial PCB trial burn in the U.S. was conducted at ENSCO. This trial burn was completed over a four-day period and consisted of a background burn (no PCBs were destroyed) and three PCB burns (liquid PCBs and solid electronic capacitors containing PCBs were destroyed). During the trial burn, an extensive series of tests were performed in accordance with EPA's recently published rules and regulations governing incineration of PCBs. Samples of all input streams and all output streams to and from the ENSCO incineration facility were collected on a daily basis and analyzed for PCBs.

Based on the results of these tests, it is the opinion of the contractor that the ENSCO facility has successfully completed the first PCB trial burn. The incineration facility effectively destroyed PCBs. PCBs were detected in only one effluent stream from the facility (rotary kiln ash) but the PCB level of this stream was below the lower limit of the regulations set by EPA (50 ppm).

Analytical problems arose in the use of the EPA perchlorination procedure for PCB analysis. There were positive results of non-PCB origin (i.e., presence of decachlorobiphenyl which was not formed from PCBs). This was confirmed by the use of gas chromatography/mass spectrometry (GC/MS) on samples which were not perchlorinated.

# SECTION 1

# INTRODUCTION

This section of the report presents a brief summary of the technology used for the disposal of PCBs by incineration. A more detailed overview of this disposal technology is available in an EPRI report (FP-1207, Volume 1) entitled "Disposal of Polychlorinated Biphenyls and PCB-Contaminated Materials."

Since the early 1970s, when PCBs were first identified as a serious environmental hazard, considerable research effort has gone into development of safe disposal techniques. Incineration has received the most attention, since this disposal technique actually destroys PCBs rather than simply containing them (eg. chemical landfill) where the possibility still exists for the PCBs to enter the environment at some later date.

There is no authoritative reference which can be cited which completely describes the incineration conditions required for total destruction of PCBs. However, a number of studies have been conducted using a variety of combustion devices to thermally destroy PCBs. Tests have been conducted in cement kilns, utility boilers, hazardous waste incinerators and sludge incinerators to determine their PCB destruction efficiency. These kinds of combustion devices have been selected since they can provide the retention time, turbulence and temperature characteristics required to destroy PCBs, which are among the most thermally stable hazardous compounds in use today. Based on these test results and other PCB combustion research done on laboratory scale devices, the EPA has promulgated a set of rules and regulations (40 CFR Part 761, Vol. 44, No. 106, May 31, 1979) governing the destruction of PCBs by incineration. These rules and regulations specify the combustion conditions which a combustion device must provide to effectively destroy PCBs. EPA has also specified the types of PCBs which may be destroyed in a given combustion device recognizing that not all combustion devices can handle all types of PCBs. Finally, EPA has specified the type of pollution control device required to control the pollutants generated by the incineration process and has set stringent PCB emission and monitoring standards commensurate with this effective combustion criteria and control technology.

The PCB trial burn at the ENSCO facility in El Dorado, Arkansas is the first commercial attempt to destroy PCBs in accordance with these new rules and regulations developed by EPA. The results from this trial burn will demonstrate whether or not PCBs can be effectively destroyed using these criteria.

## SECTION 2

## PROCESS DESCRIPTION

ENSCO owns and operates a solid and liquid waste treatment facility as illustrated in Figure 2-1. The basic equipment arrangement used by ENSCO to conduct this PCB trial burn is shown in Figure 2-2. This section of the report summarizes the manner in which the process equipment was operated during this trial burn. The descriptions contained in this section were obtained from several conversations with ENSCO personnel and from observations made by Acurex during and after the trial burn.

### 2.1 SOLID WASTE SHREDDERS

Figure 2-3 is a photograph of the shredder structure which houses two hammermills. These two hammermills are manufactured by Gruendler Crusher and Pulverizer Inc. and operate in series. The primary hammermill (approximately 30 hp) shreds the small electronic capacitors (2 in. by 2 in. by 4 in.) which then drop into the secondary hammermill (approximately 50 hp) and are reduced to 0.5 inch square pieces referred to as "fluff". These capacitors are contained in weighed, 55-gal drums. The contents of these drums were manually dumped into the primary shredder. The capacitors (analyzed by Northrop Services) contained 31.1 ± 5.1 percent by weight of oil. This oil was 79.7 percent by weight Aroclor® 1016 (i.e., the capacitors contained 24.8 ± 8.5 percent by weight of Aroclor® 1016). An ultimate analysis of these same type of capacitors done three years ago (by TRW on EPA Contract 68-01-2966) yielded the following results -- 35.4 percent by weight carbon, 3.3 percent hydrogen, 12.4 percent chlorine, 16.9 percent oxygen, 32.0 percent ash and a higher heating value of 5,560 Btu/lb. The average feedrate of capacitors for the three PCB tests was 980 lb/hr. PCBs accounted for 243 lb/hr of this total amount. No large electrical utility capacitors were incinerated during this trial burn.

Liquid PCBs (80.9 ± 4 percent by weight of Aroclor® 1016(determined by Northrop Services) are gravity-fed into the hopper under the secondary hammermill where they mix with the "fluff" and actually adsorb onto the fluff (i.e., there is

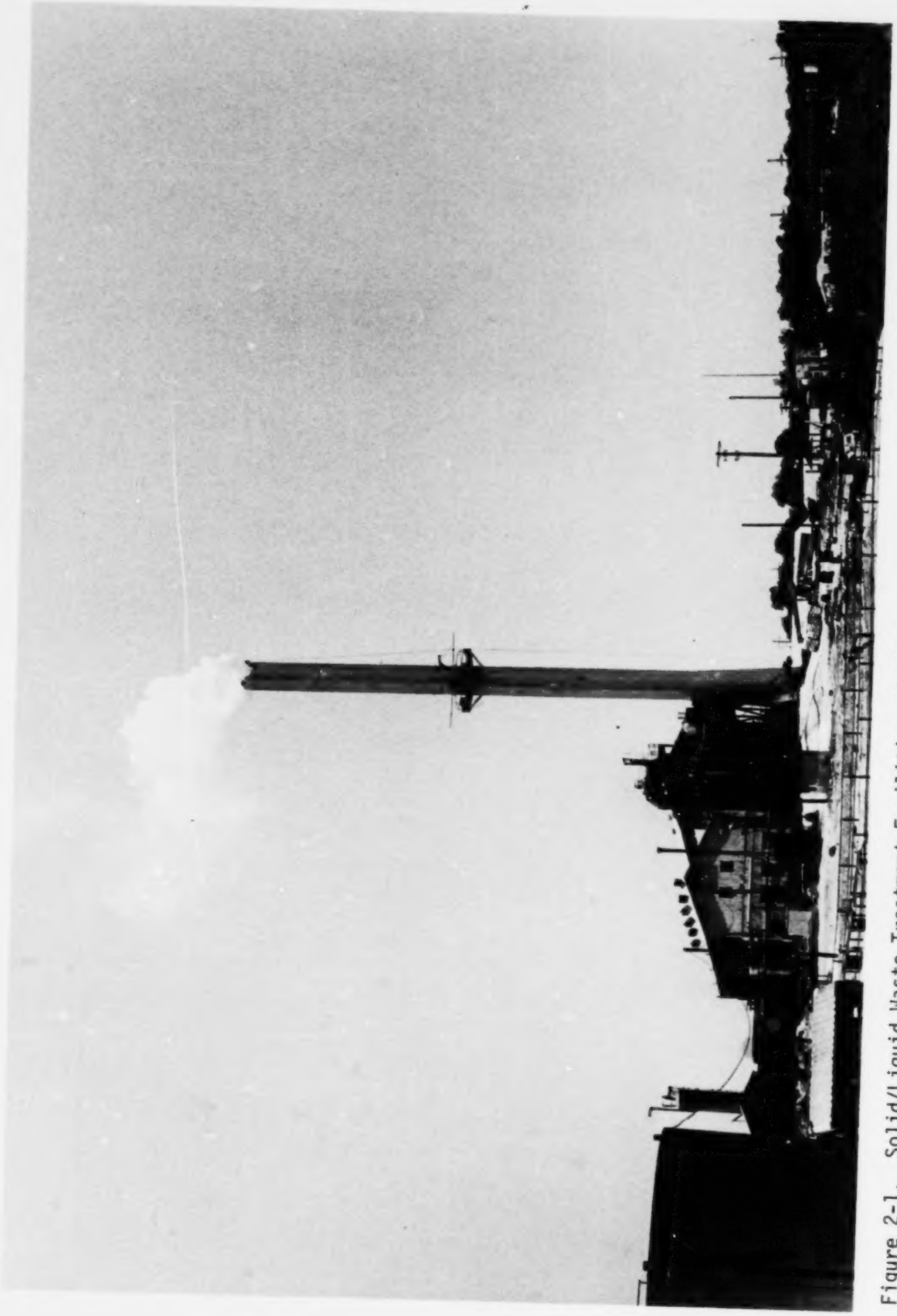

Figure 2-1. Solid/Liquid Waste Treatment Facilities of ENSCO

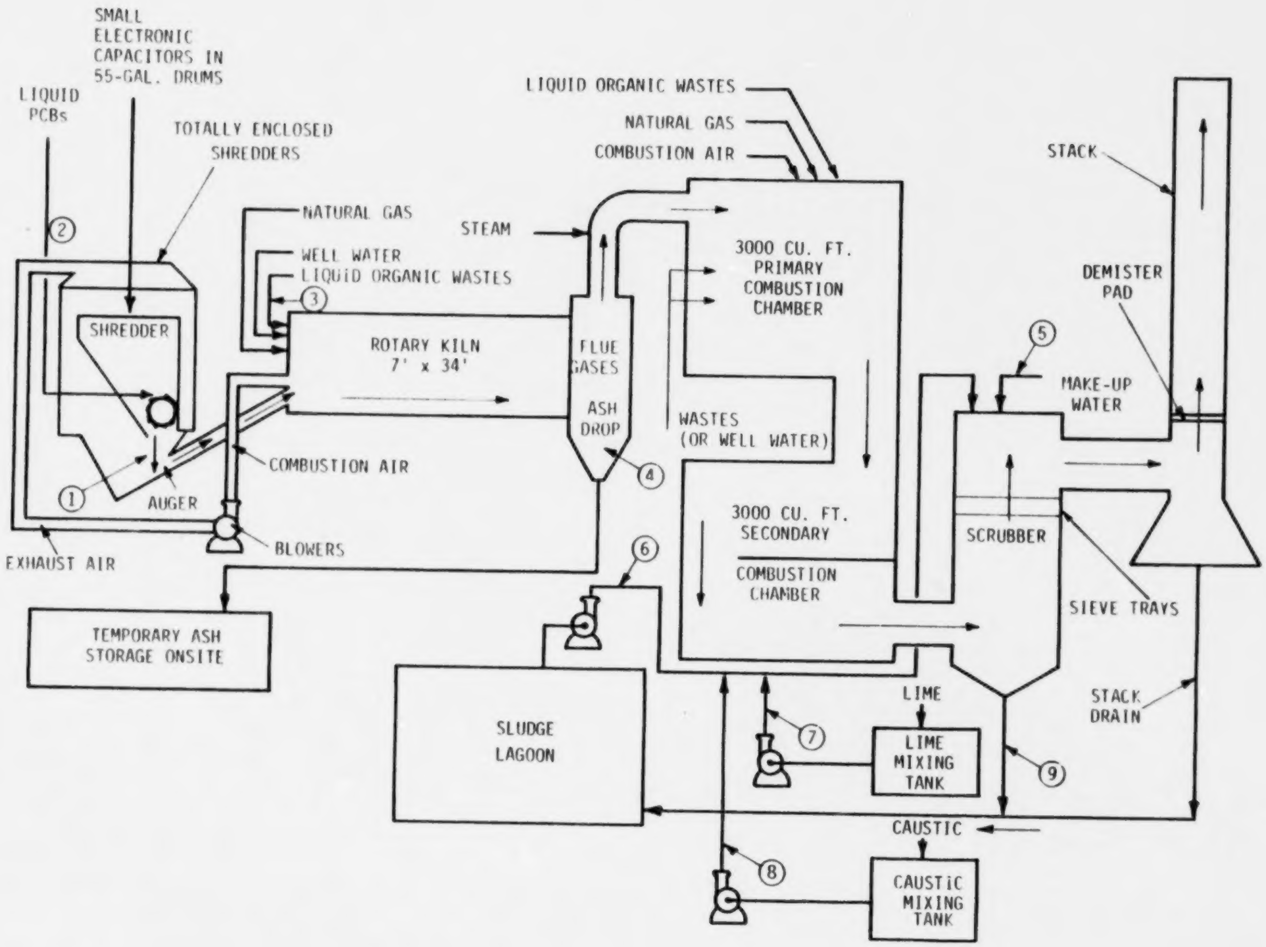

Figure 2-2. Process Flowchart of ENSCO Facilities

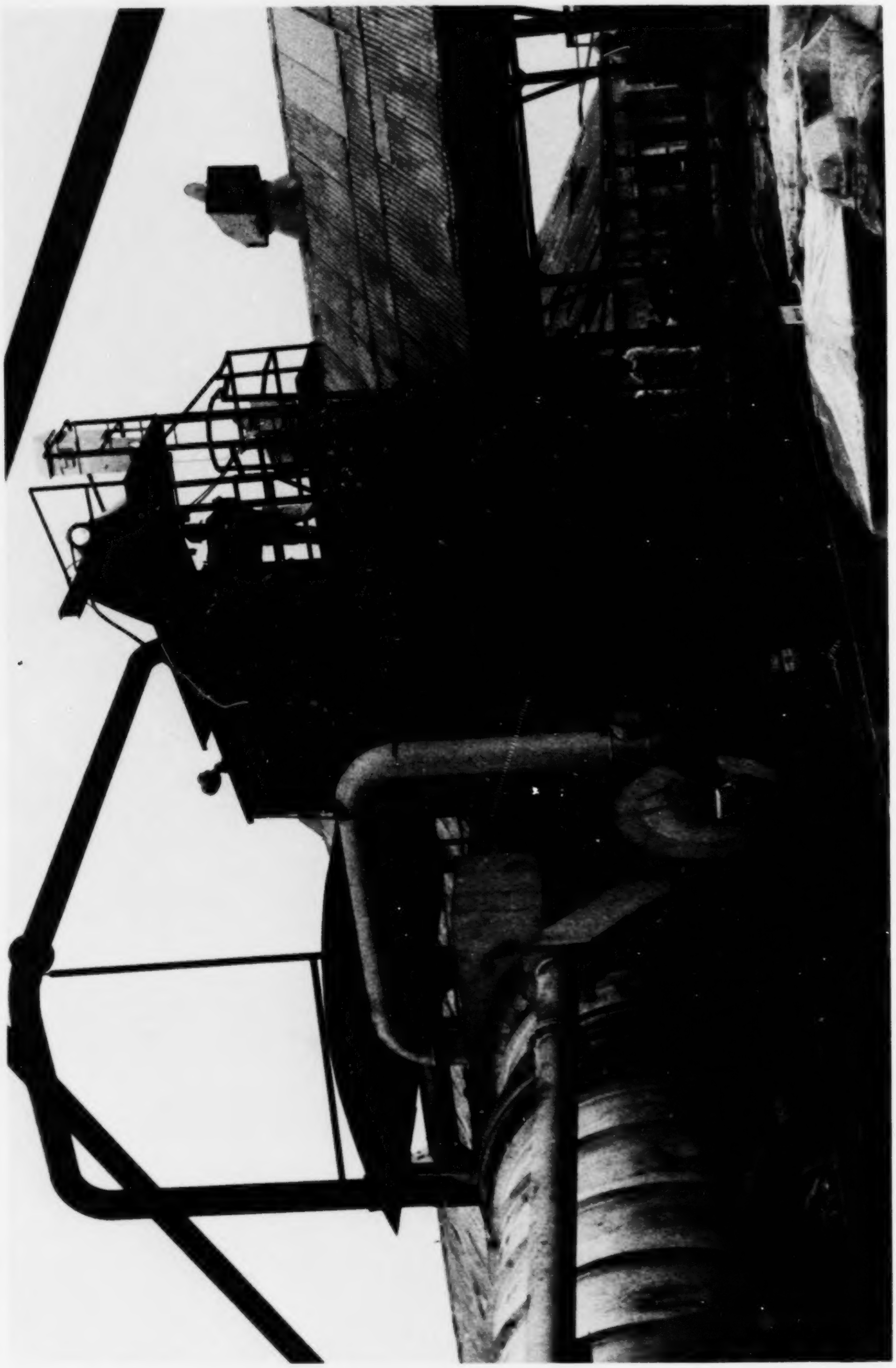

Figure 2-3. Capacitor Shredder Structure

no excess liquid PCB). The PCB soaked fluff then falls into the auger for transport to the rotary kiln. An ultimate analysis (by Northrop Services) of the liquid PCBs indicated the following composition and heating values -- 54.8 percent by weight carbon, 2.6 percent hydrogen, 42.6 percent chlorine and 8,820 Btu/lb. The average feedrate during this trial burn was 486 lb/hr. Table 2-1 summarizes the feedrate data obtained during the trial burn.

Table 2-1

FEEDRATES OF SOLID CAPACITORS AND LIQUID PCBs DURING TRIAL BURN

| Component Feedrate[a] | 10/15/80 | 10/16/80 | 10/17/80 | 10/18/80 | Average[c] |
|---|---|---|---|---|---|
| Solid Capacitors | 860[b] | 1055 | 870 | 1015 | 980 |
| PCB's in Solid Capacitors | 0 | 268 | 224 | 238 | 243 |
| Liquid PCBs | 253[b] | 447 | 478 | 533 | 486 |
| PCBs in Liquid | 0 | 362 | 387 | 431 | 393 |

---

[a] Feedrates in lb/hr (determined by ENSCO and Northrop)
[b] Non-PCB materials during background burn
[c] Average of 10/16, 10/17, 10/18

The hoppers of the hammermills are maintained under slight negative pressure (approximately 0.1 in. wg) to prevent the release of PCBs into the ambient air during the shredding operation. Suction on the hoppers is provided by a blower (approximately 3000 cfm at 1 psi) and this exhaust air is used as combustion air for the rotary kiln.

## 2.2 ROTARY KILN

The PCB soaked fluff is discharged by the auger into the front of the rotary kiln as illustrated in Figure 2-4. The rotary kiln is 34 feet long and has an internal diameter of 7 feet. The kiln is refractory lined and rotates at approximately 0.5 rpm which results in a retention time of approximately 60 minutes for solids

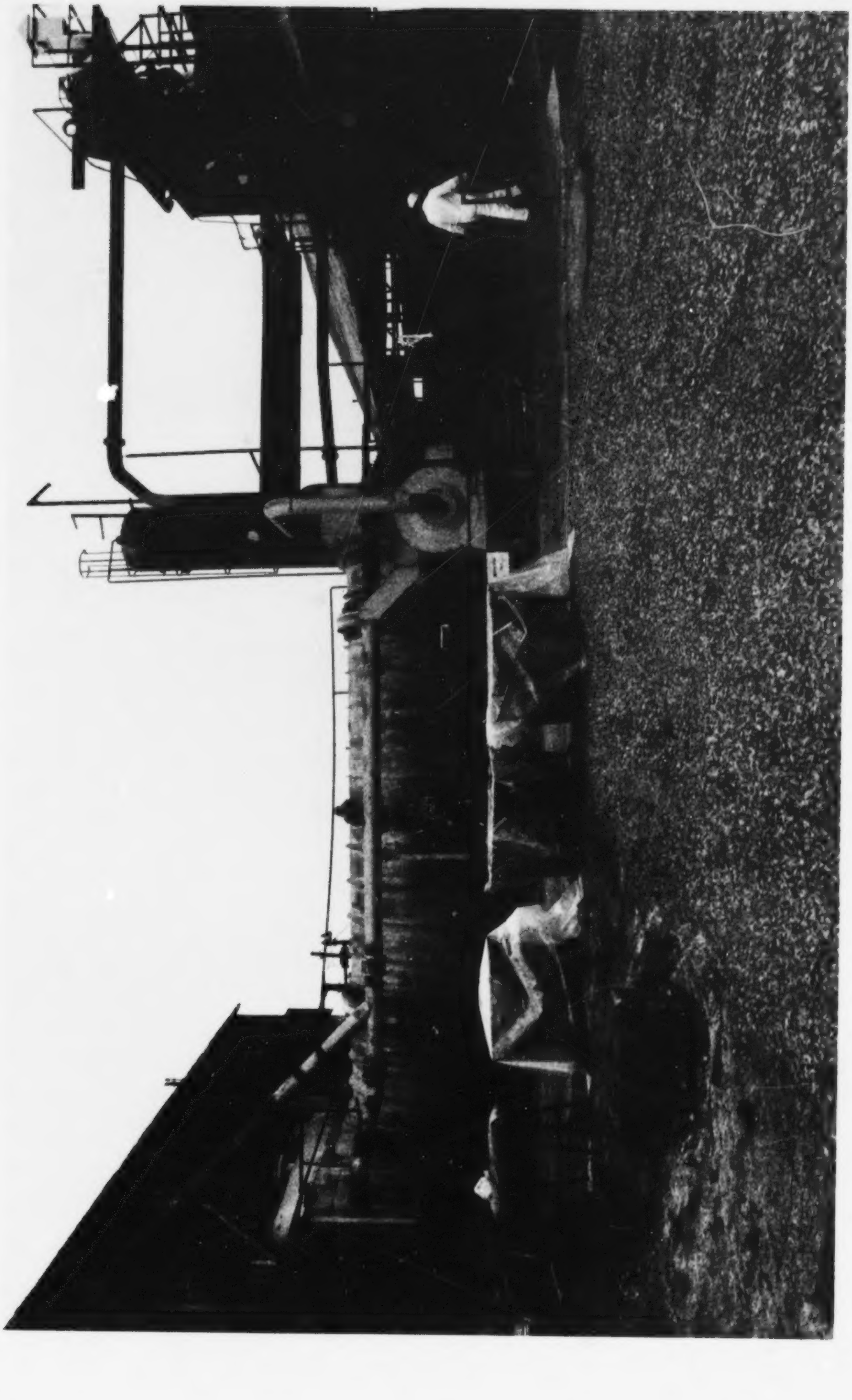

Figure 2-4. Rotary Kiln

and approximately 3.7 seconds for gaseous material. There are lifters protruding from the refractory to ensure solid material is "turned over" as it passes through the kiln. The temperature inside the kiln (frontend) is measured by a thermocouple and varied from 1200 to 1500°F (average 1400°F) during the tests. Table 2-2 illustrates the temperature variation with time. Liquid organic waste (chlorinated aliphatic hydrocarbons), well water and natural gas are also injected into the front of the rotary kiln. The characteristics of the liquid organic waste feed stream is summarized in Table 2-3. Analysis of the natural gas (by ENSCO) yielded 75.0 percent by weight carbon, 25.0 percent hydrogen and a heating value of 24,190 Btu/lb. The average well water injection rate is 373 gal/hr. Only the total flowrates of liquid organic waste, natural gas, and well water are measured. There is no separate flowrate measurement for the rotary kiln or primary combustion chamber. Approximately 75 percent of the total natural gas (averaged 2,260 scf/hr) is consumed in the rotary kiln to ignite the waste material being fired. The remaining 25 percent of the natural gas is used in the primary combustion chamber through the two burners (in the large pilot lights). Ten percent of the total liquid organic waste (averaged 590 gal/hr) is injected in the rotary kiln compared with 90 percent in the primary combustion chamber. Table 2-4 summarizes the daily feedrates of these components.

A drag chain is used to remove the ash remaining in the kiln after destruction of all the combustible matter. For these tests, the kiln ash was captured in steel hoppers (foreground of Figure 2-4), covered with polyethylene and stored onsite. The total volume of kiln ash produced during the trial burn was approximately 127.6 $ft^3$ (no data for individual days). The effective density of this ash was approximately 0.86 $lb/ft^3$. Hence, the total amount of ash collected was approximately 109.7 lb.

## 2.3 AFTERBURNER

The gases leaving the rotary kiln are injected with steam and fed into the primary combustion chamber of the afterburner. This is a refractory lined chamber (approximately 3000 $ft^3$) into which most of the liquid organic waste is fired. It has a residence time of approximately 2.19 seconds. The temperature of this chamber is measured by a thermocouple in the crossover duct (between the primary and secondary combustion chambers). The average temperatures measured during the tests were 2320°F, 2280°F, 2270°F and 2290°F. The liquid organic waste has a low ash content (approximately 3.7 percent by weight) and the ash is molten

## Table 2-2
## COMBUSTION TEMPERATURES VERSUS TIME FOR TRIAL BURN

| | | 10/15/79 | | | 10/16/79 | | | 10/17/79 | | | 10/18/79 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Time** | **Kiln** | **Afterburner** | **Hot Duct** | **Kiln** | **Afterburner** | **Hot Duct** | **Kiln** | **Afterburner** | **Hot Duct** | **Kiln** | **Afterburner** | **Hot Duct** |
| 10:00 am | | | | | 2280 | 1875 | | 2300 | 1910 | 1340 | 2225 | 1890 |
| | | | | | 2350 | 1900 | | 2200 | 1850 | 1470 | 2260 | 1890 |
| | | | | | 2175 | 1825 | | 2250 | 1850 | 1500 | 2280 | 1900 |
| | | | | | 2275 | 1890 | | 2260 | 1850 | 1280 | 2320 | 1925 |
| 11:00 am | 1240 | 2290 | 1890 | | 2225 | 1850 | 1130 | 2260 | 1860 | 1400 | 2290 | 1925 |
| | 1440 | 2375 | 1950 | 1310 | 2275 | 1850 | | 2240 | 1875 | 1250 | 2380 | 1950 |
| | 1480 | 2300 | 1900 | 1450 | 2290 | 1890 | 1270 | 2240 | 1865 | 1370 | 2350 | 1975 |
| | 1400 | 2360 | 1890 | 1400 | 2250 | 1890 | 1300 | 2300 | 1940 | 1400 | 2280 | 1910 |
| 12:00 | 1410 | 2300 | 1875 | 1420 | 2400 | 2000 | 1400 | 2190 | 1870 | 1450 | 2300 | 1940 |
| | 1440 | 2325 | 1895 | 1320 | 2400 | 1040 | 1460 | 2280 | 1900 | 1470 | 2300 | 1940 |
| | 1480 | 2250 | 1875 | 1310 | 2225 | 1900 | 1320 | 2300 | 1910 | 1500 | 2225 | 1900 |
| | 1320 | 2350 | 1900 | 1320 | 2300 | 1940 | 1450 | 2290 | 1900 | 1460 | 2280 | 1900 |
| 1:00 pm | 1410 | 2280 | 1880 | 1380 | 2200 | 1860 | 1425 | 2240 | 1890 | 1480 | 2300 | 1950 |
| | 1450 | 2400 | 1980 | 1280 | 2300 | 1920 | 1480 | 2280 | 1920 | 1380 | 2300 | 1950 |
| | 1400 | 2350 | 1980 | 1300 | 2350 | 1940 | 1300 | 2250 | 1900 | 1380 | 2350 | 1930 |
| | 1480 | 2400 | 1980 | 1360 | 2200 | 1825 | 1290 | 2350 | 2080 | 1360 | 2220 | 1905 |
| 2:00 pm | 1480 | 2200 | 1940 | 1340 | 2300 | 1970 | 1500 | 2300 | 1950 | 1350 | 2250 | 1900 |
| | 1470 | 2200 | 1830 | 1350 | 2175 | 1890 | | 2250 | 1900 | 1380 | | |
| | 1450 | 2250 | 1850 | 1240 | 2390 | 1980 | | 2225 | 1975 | 1400 | | |
| | 1300 | 2240 | 1875 | 1300 | 2425 | 2010 | | 2230 | 1890 | 1410 | 2300 | 1910 |
| 3:00 pm | 1310 | 2280 | 1910 | 1400 | 2290 | 1950 | | 2250 | 1900 | 1290 | 2225 | 1990 |
| | 1400 | 2410 | 1925 | 1200 | 2260 | 1900 | 1400 | 2240 | 1900 | 1280 | 2250 | 1890 |
| | 1360 | 2325 | 1925 | 1300 | 2230 | 1890 | 1380 | 2300 | 1905 | 1480 | 2300 | 1900 |
| | 1400 | 2480 | 2000 | 1480 | 2300 | 1940 | 1500 | 2410 | 1990 | 1320 | 2300 | 1890 |
| 4:00 pm | 1400 | 2350 | 1915 | 1300 | 2300 | 1925 | 1370 | 2300 | 1940 | 1480 | 2280 | 1890 |
| | 1450 | 2300 | 1905 | 1350 | 2310 | 1980 | 1300 | 2225 | 1880 | 1300 | 2250 | 1890 |
| | 1380 | 2400 | 1985 | 1360 | 2225 | 1925 | 1370 | 2250 | 1890 | | | |
| | 1400 | 2280 | 1910 | 1350 | 2200 | 1900 | 1280 | 2275 | 1925 | | | |
| 5:00 pm | 1400 | 2240 | 1860 | 1480 | 2250 | 1900 | 1300 | 2300 | 1940 | | | |
| | 1400 | 2200 | 1850 | 1320 | 2250 | 1900 | 1400 | 2260 | 1915 | | | |
| | 1400 | 2280 | 1915 | 1430 | 2200 | 1880 | 1420 | 2275 | 1910 | | | |
| | | | | 1350 | 2180 | 1820 | 1410 | | | | | |
| 6:00 pm | | | | 1280 | 2190 | 1875 | 1300 | 2300 | 1950 | | | |
| | | | | 1380 | 2300 | 1900 | 1400 | 2200 | 1975 | | | |
| | | | | | | 1925 | 1280 | 2175 | 1830 | | | |
| | | | | | | | 1300 | 2300 | 1900 | | | |
| 7:00 pm | | | | | | | 1400 | 2250 | 1840 | | | |
| | | | | | | | 1220 | 2180 | 1840 | | | |
| | | | | | | | 1400 | 2260 | 1900 | | | |
| | | | | | | | 1400 | 2285 | 1925 | | | |
| 8:00 pm | | | | | | | 1450 | 2300 | 1950 | | | |

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NOTE: All temperatures in °F (determined by ENSCO)
Kiln = Rotary kiln temperature
Afterburner = Crossover duct temperature
Hot Duct = Refractory lined duct prior to scrubber

## Table 2-3

## LIQUID ORGANIC WASTE CHARACTERISTICS

| Property of Waste[a] | Test 1[b] | Test 2 | Test 3 | Test 4 | Average[c] |
|---|---|---|---|---|---|
| Density (lb/gal) | 10.83 | 10.83 | 10.83 | 10.83 | 10.83 |
| HHV (Btu/lb) | 7,055.0 | 6,464.0 | 6,860.0 | 7,155.0 | 6,826.0 |
| Chlorine (% wt) | 53.0 | 50.0 | 52.0 | 58.0 | 53.33 |
| Ash (% wt) | 3.8 | 2.85 | 4.29 | 3.9 | 3.68 |
| Sulfur (ppm) | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| pH | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |

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[a] Also contained 24.9 percent by weight carbon, 8.2 percent hydrogen and 10 percent oxygen (analyzed by ENSCO)
[b] Background test; no PCBs burned
[c] Average of 10/16, 10/17, 10/18

## Table 2-4

## FEEDRATES OF LIQUID ORGANIC WASTE, WELL WATER, AND STEAM DURING TRIAL BURN

| Component Feedrate | 10/15/80 | 10/16/80 | 10/17/80 | 10/18/80 | Average[a] |
|---|---|---|---|---|---|
| Liquid Organic Waste[b] | 525 | 591 | 616 | 562 | 590 |
| Natural Gas[c] | 11,025 | 3,100 | 1,300 | 2,380 | 2,260 |
| Well Water[b] | 384 | 415 | 292 | 411 | 373 |
| Steam[d] | 1,050 | 1,050 | 1,050 | 1,050 | 1,050 |

---

[a] Average of 10/16, 10/17, 10/18 (determined by ENSCO)
[b] Feedrates in gal/hr
[c] Feedrate in scf/hr
[d] Feedrate in gal/hr

at these temperatures and collects in a pool on the combustion chamber floor. A slag tap on one side of this chamber is used to remove excess molten slag.

The secondary combustion chamber (approximately 3000 $ft^3$) is baffled to promote mixing of the combustion gases. The temperatures measured by a thermocouple located in the hot, refractory lined duct between this chamber and the scrubber were 1920°F, 1900°F, 1910°F and 1920°F during the tests. The retention time in this chamber is approximately 2.11 seconds. The total retention time of both chambers and the crossover duct is approximately 4.53 seconds.

## 2.4 VENTURI JET SCRUBBER

The combustion gases leaving the secondary combustion chamber enter a refractory lined duct which provides additional residence time (approximately 0.18 second) to complete combustion. The gases are quenched as they enter the bottom of the scrubber. The quenched gases are drawn through the two sets of sieve trays which are irrigated with recycled scrubber liquor, lime and caustic solution to remove particulates and neutralize acidic gases ($HC\ell$ and $SO_2$). This spent scrubber liquor falls to the bottom of the scrubber and drains to a tank which overflows to the sludge lagoon for recycle. The gaseous and fine particulates not removed by the sieve trays are then passed through a venturi section of ductwork (duct reduces from 48 in. to 30 in. and expands to 48 in.) into which recycled scrubber water is sprayed through a jet. Makeup well water is also injected to compensate for the loss of moisture up the stack.

A sample of these cleaned gases are extracted for analysis by continuous stack gas monitors (CO, $O_2$) and by Orsat ($CO_2$) to determine combustion efficiency. ENSCO has installed an Ecolyzer Model 3103 CO analyzer (electrolytic fuel cell type) with dual ranges of 0 to 600 ppm and 0 to 100 ppm full scale. This monitor is used to measure CO content of the gases on the 0 to 100 ppm scale and was calibrated using certified gas supplied by EPA (7.0, 20.1 and 41.5 ppm CO). The set point for the CO monitor alarm is 50 ppm. This alarm went off on several occasions and shutoff the PCB feed to the rotary kiln but these shutoffs were not sustained for very long periods of time. CO levels exceeded 50 ppm on those occasions when fluctuations in the liquid organic waste feedrate created a fuel rich combustion condition which, in turn, resulted in higher CO levels. The average CO value measured during the tests was $<10$ ppm. $O_2$ is measured using a

Taylor-Servomax Model OA-269 paramagnetic type analyzer with a range of 0 to 25 percent. The set point for this analyzer was 4.5 percent to ensure there is always excess oxygen available for combustion. Oxygen levels averaged 13.4 percent. ENSCO operations personnel used an Fyrite analyzer to measure the $CO_2$ content of the gases every 15 minutes. $CO_2$ values averaged 5.5 percent during the trial burn. The nondispersive infrared $CO_2$ analyzer was not yet operational during the tests.

The gases leaving the scrubber pass through a demister pad to remove entrained water droplets and travel up the stack and enter the atmosphere. The stack is equipped with a drain to collect the condensate which eventually returns to the lagoon. According to ENSCO, the mesh demister pad shrank during the trial burn leaving a gap, which varied from 0 to 6 in. in width around one half of its circumference, between it and the stack wall. Subsequent to the trial burn this demister has been replaced by a Chevron type demister supplied by Munters Corporation. Fresh makeup water is also being used in place of recycled scrubber liquor to rinse the demister to minimize carryover of salts from the spent scrubber liquor.

# SECTION 3

# SAMPLING LOCATIONS, EQUIPMENT AND PROCEDURES

This section of the report summarizes the locations in the process where samples were collected, the equipment used to collect the samples and the procedures used to operate this equipment during the trial burn.

## 3.1 LOCATION OF SAMPLING SITES

Figure 2-2 illustrated the location of the sampling sites in the waste treatment process. A description of each site is presented in the following subsections.

### 3.1.1 Process Sampling Sites

A number of samples (inputs and outputs) from various locations in the process streams were collected during each test. These sites were identified in Figure 2-2 and are described in further detail in the following paragraphs.

3.1.1.1 Shredded Electronic Capacitors -- Sample Stream 1. Samples of the shredded electronic capacitors (fluff) were collected from the hopper of the last hammermill just before the fluff fell into the auger system. These samples were collected by Northrop Services Inc., of Little Rock, Arkansas under contract to ENSCO. These fluff samples were collected in 1-qt steel cans and were composited into cans of 1-gal capacity. All cans were new, triple rinsed with hexane (pesticide grade), dried and sealed prior to field use. The cans were sealed at all times except when fluff was being placed in the cans.

3.1.1.2 Liquid PCBs -- Sample Stream 2. Samples of liquid PCBs which were gravity fed into this same hopper were also collected by Northrop Services. These samples were collected in the same type of steel cans used to collect the fluff samples.

3.1.1.3 Liquid Organic Waste -- Sample Stream 3. Figure 3-1 illustrates the sampling site at which samples of the chlorinated organic waste stream (used as part of fuel for the rotary kiln) were collected. Samples were taken from a valve in the pipeline just prior to introduction to the rotary kiln.

3.1.1.4 Rotary Kiln Ash -- Sample Stream 4. Samples of the ash from the rotary kiln were taken directly from the steel ash hopper as illustrated in Figure 3-2.

3.1.1.5 Well Water -- Sample Stream 5. Figure 3-3 illustrates the sampling site at which samples of the well water (makeup water to scrubber and water injected

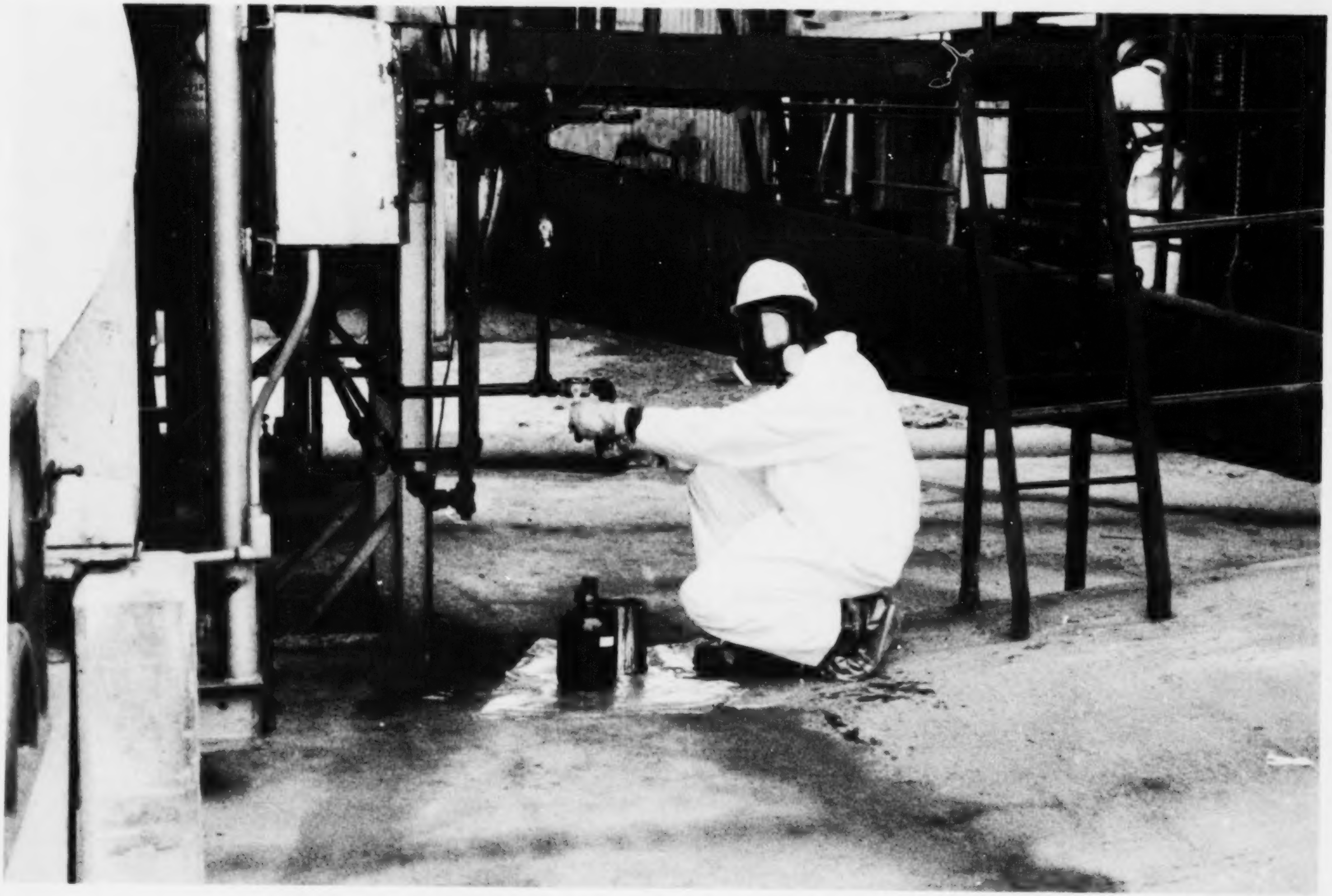

Figure 3-1. Liquid Organic Waste Sampling Site

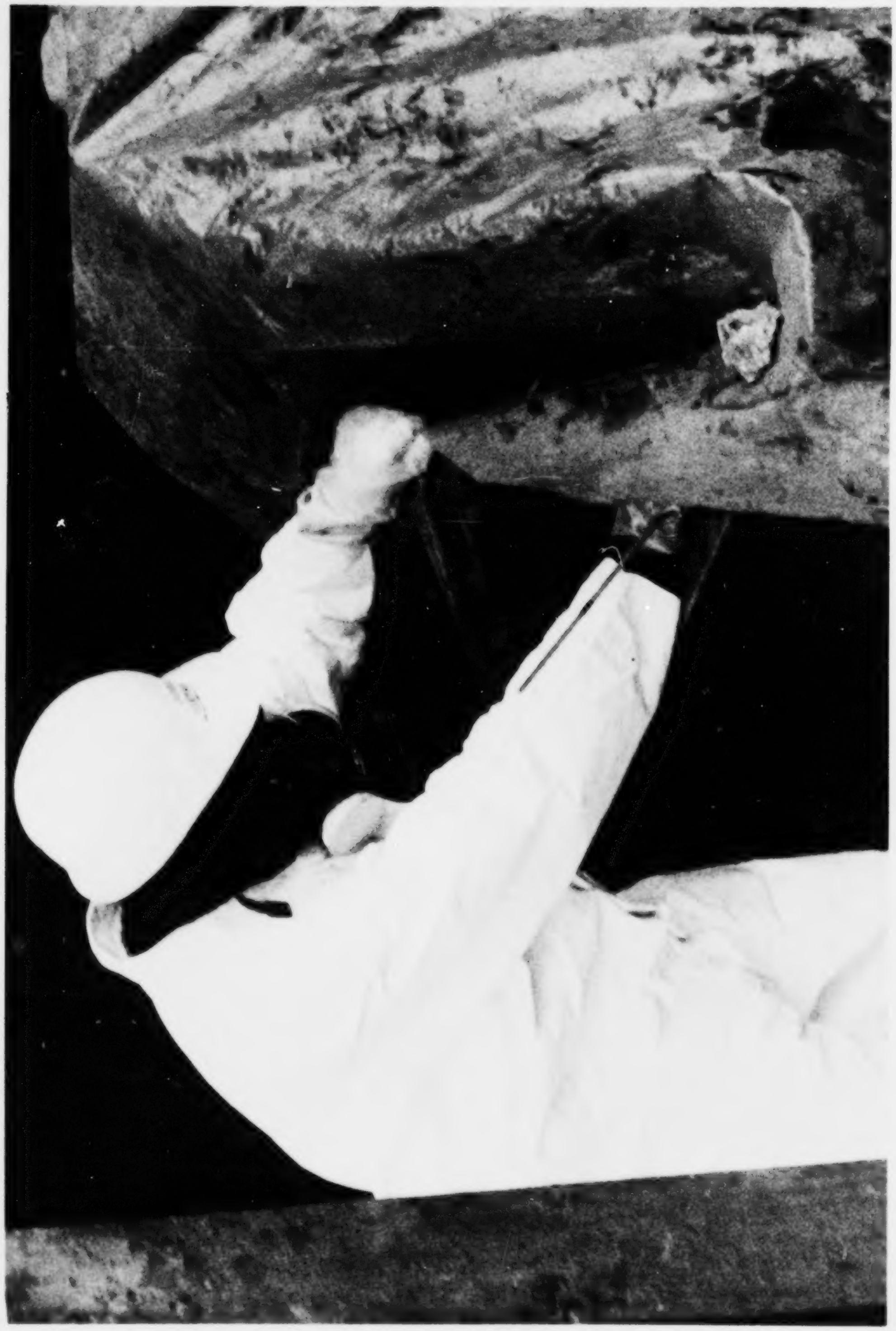

Figure 3-2. Rotary Kiln Ash Sampling Site

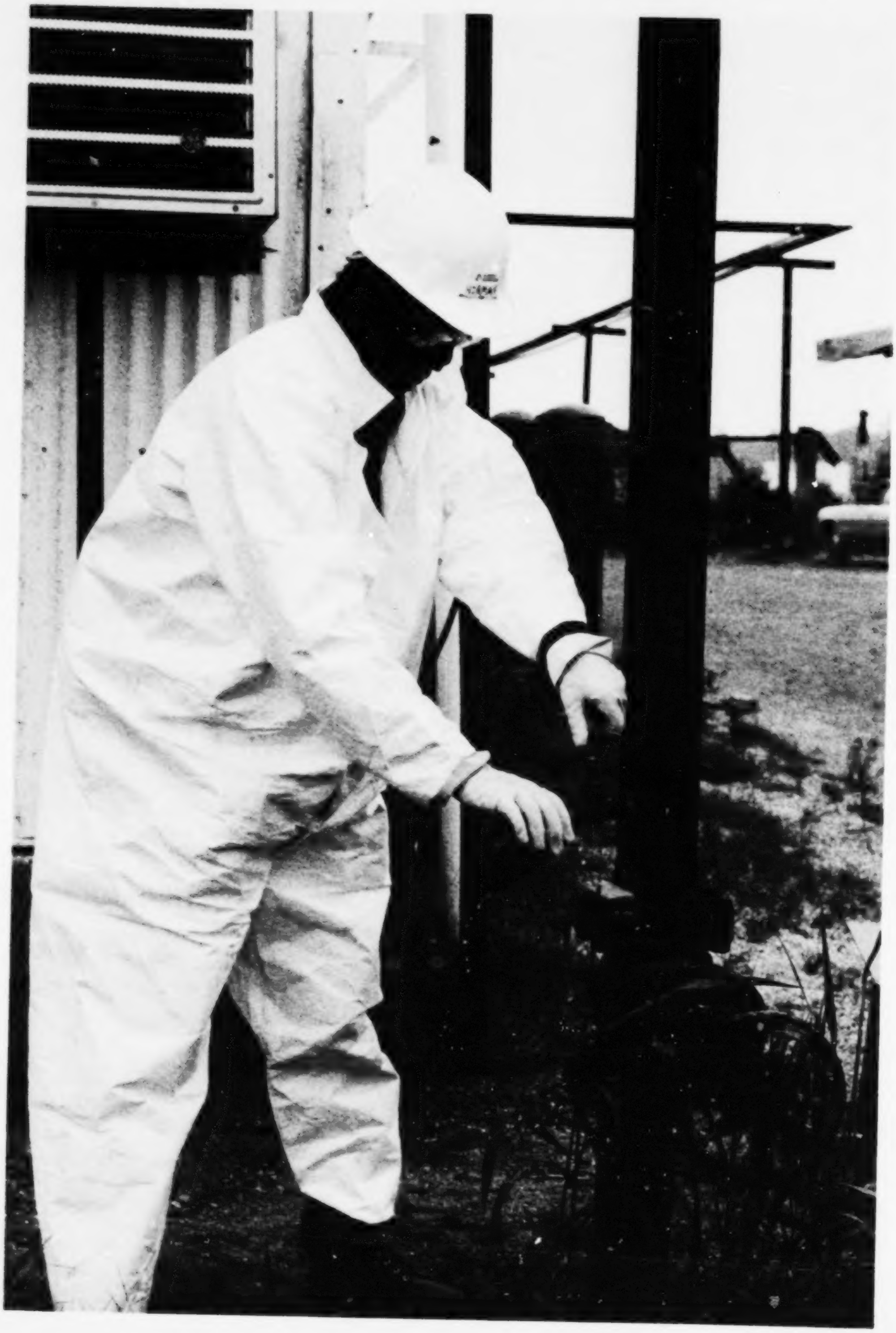

Figure 3-3. Well Water Sampling Site

into kiln) were collected. Samples were taken from a valve in the well water pipeline leading to the scrubber.

3.1.1.6 Recycled Scrubber Liquor -- Sample Stream 6. Samples of the scrubber liquor which was recycled to the scrubber from the sludge lagoon were taken directly from the pipeline leading to the scrubber as shown in Figure 3-4.

3.1.1.7 Lime Slurry -- Sample Stream 7. Figure 3-5 illustrates the sampling site used to obtain samples of the lime slurry. These samples were collected from a valve in the pipeline leading from the lime mixing tank to the scrubber.

3.1.1.8 Caustic Solution -- Sample Stream 8. Samples of the 50 percent caustic solution injected into the scrubber were collected from the pipeline leading from the caustic tank to the venturi scrubber as shown in Figure 3-6.

3.1.1.9 Scrubber Liquor -- Sample Stream 9. Samples of the spent venturi scrubber liquor were collected from an open portion of the pipeline transporting the liquor to the sludge lagoon as shown in Figure 3-7.

### 3.1.2 Stack Sampling Site

Samples of the stack gases were collected at a platform which was located eight stack diameters downstream of the breeching entering the base of the stack and more than two stack diameters from the stack exit.

## 3.2 SAMPLING EQUIPMENT

This subsection of the report details the equipment used to collect the various types of samples during the trial burn.

### 3.2.1 Process Stream Sampling Equipment

Each liquid process stream (liquid organic waste, well water, recycled scrubber liquor, scrubber liquor, lime slurry and caustic solution) sample was collected in a clean, amber glass jar (500 ml) with a teflon seal in the cap. The individual 500 ml samples were transferred to a clean, amber glass jug (1 gal) to obtain a composite sample for each test. Each jug was labelled, sealed and then transported to Mountain View for analysis. The rotary kiln ash was sampled with a clean steel can (1 qt) attached to clean steel handle. The individual quart samples of ash were transferred to a clean, galvanized steel garbage can (20 gal) to composite the ash sample for each test. After thoroughly mixing the ash in the can, a clean, amber glass jar (250 ml) was used to collect and transport the composite sample of ash to Mountain View for analysis.

The individual shredded solid capacitors and the liquid PCBs samples were collected in new, 1-qt steel cans which were subsequently composited in new, 1-gal steel cans.

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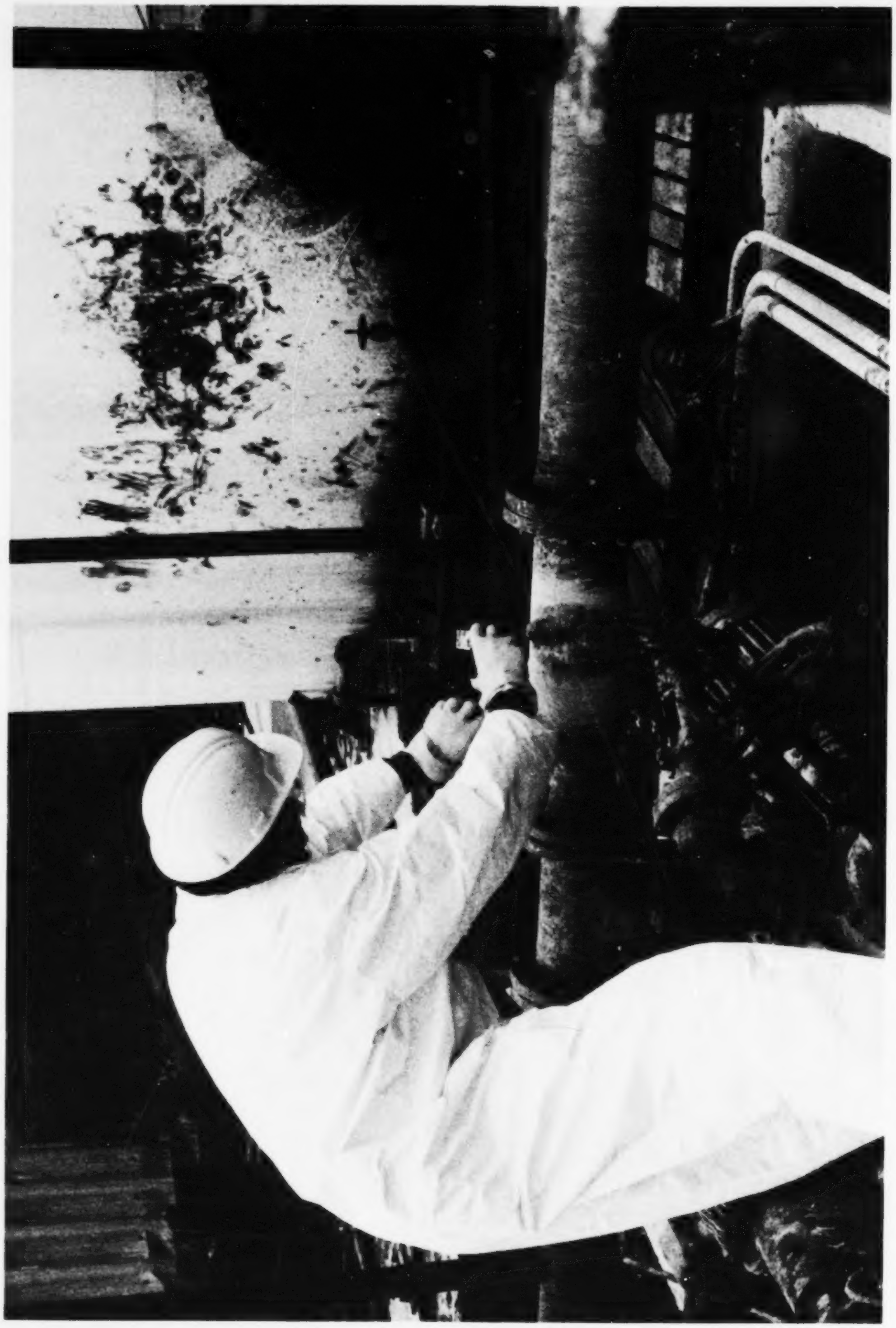

Figure 3-4. Recycled Scrubber Liquor Sampling Site

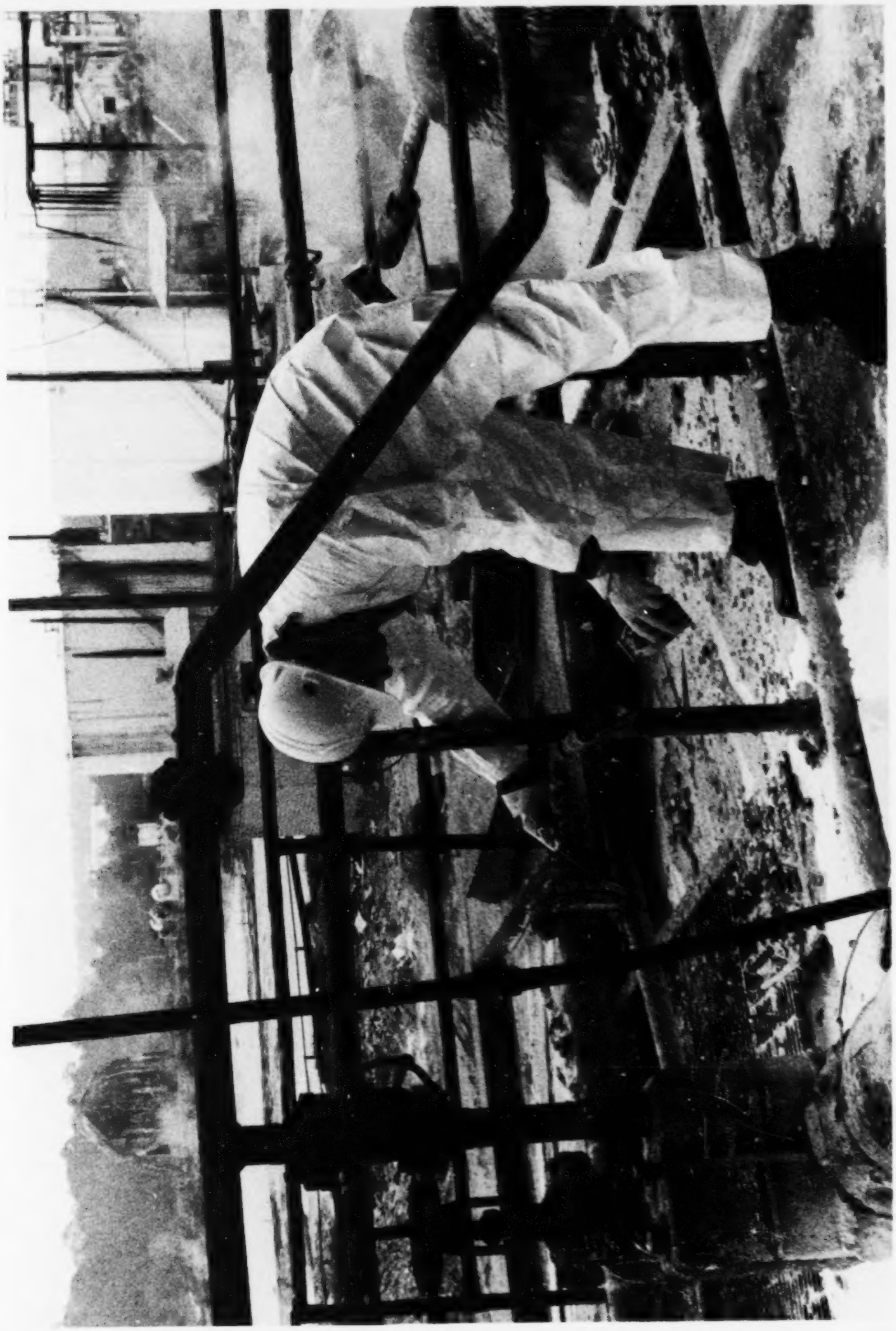

Figure 3-5. Lime Slurry Sampling Site

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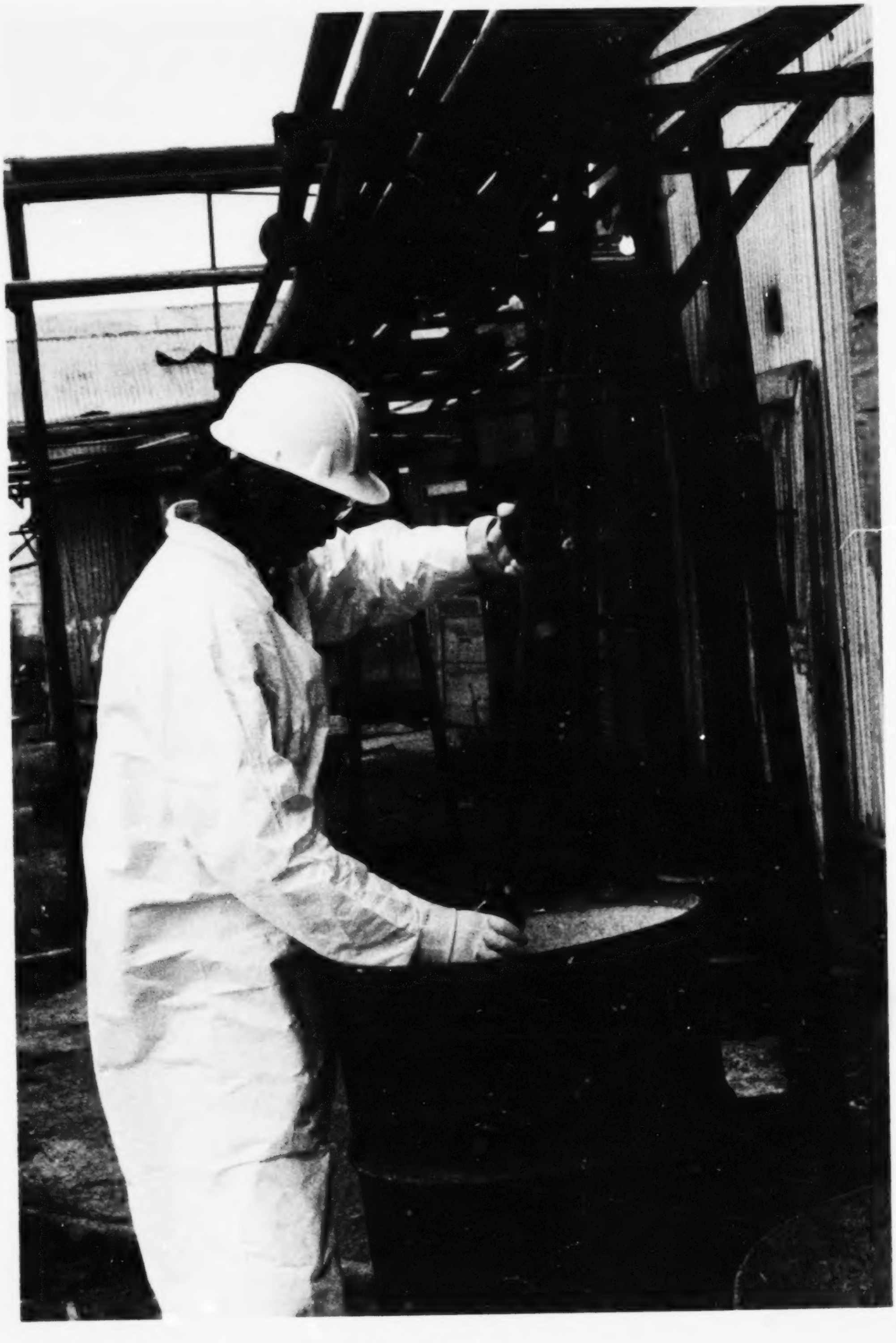

Figure 3-6. Caustic Solution Sampling Site

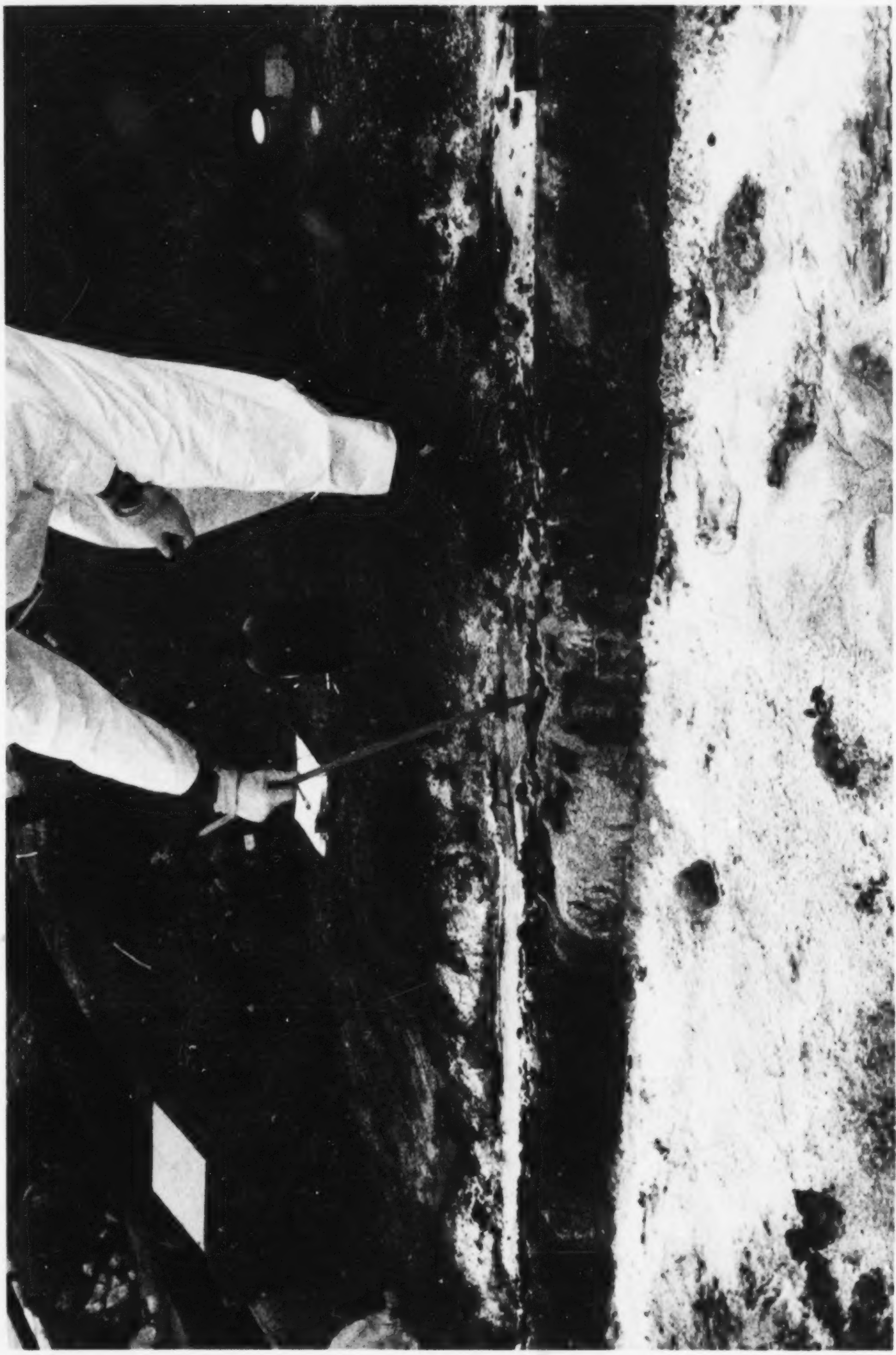

Figure 3-7. Scrubber Liquor Sampling Site

### 3.2.2 Stack Sampling Equipment

Various sampling trains were used to sample the stack gases during the trial burn. Each type of train is described in detail in the following paragraphs.

3.2.2.1 Particulate Matter and Hydrochloric Acid Sampling Equipment. The particulate matter and hydrochloric acid (HCℓ) present in the stack gases were sampled simultaneously using an EPA Method 5 sampling train. This sampling train consisted of the following components:

- A 316 stainless steel nozzle with an inside diameter of 0.4978 in. to sample isokinetically
- A heated, 316 stainless steel lined probe, 15 ft long, equipped with thermocouples to measure the probe temperature and the stack gas temperature and an S-type pitot tube to measure the stack gas velocity pressure
- A heated, circular oven containing a 142-mm, teflon coated, stainless steel filter holder with a glass fiber filter
- A teflon lined, braided stainless steel hose to connect the outlet of the filter to the inlet of the impinger train
- An impinger train containing 5 impingers (No. 1 -- 100 ml 0.1 N NaOH, No. 2 -- 100 ml 0.1 N NaOH, No. 3 -- 100 ml 0.1 N NaOH, No. 4 -- dry, No. 5 -- 200 gm silica gel)
- A vacuum hose to connect the outlet of the impinger train to a vacuum pump
- A 10-cfm carbon vane vacuum pump modified for low leakage around the shaft
- A vacuum hose to connect the pump outlet to the control module
- A control module to measure the temperature, pressure, flowrate and gas volume of the sampled gases

The material collected in the nozzle, in the probe, on the filter paper and on the front half of the filter holder was considered to be particulate matter. The material collected on the back half of the filter holder, in the teflon hose, and trapped in the impinger train was considered to be HCℓ.

3.2.2.2 PCB and RCℓ Sampling Equipment. The PCB sampling train was identical to the train specified in the EPA manual entitled "Sampling Methods and Analytical Procedures Manual for PCB Disposal: Interim Report, Attachment E" with one exception. A packed tube of XAD-2 resin was put in series with the Florisil® tube to trap RCℓ (total chlorinated organics). This modification was made with the concurrence of EPA Region 6 since the EPA manual cited previously contains no methodology to measure RCℓ. Figure 3-8 illustrates this modification to the impinger train. Hence, the PCB/RCℓ sampling train consisted of the following components:

- A 316 stainless steel nozzle with an inside diameter of 0.371 in. to sample isokinetically
- A heated, 5-foot glass-lined probe equipped with thermocouples to measure the probe temperature and stack gas temperature and an S-type pitot tube to measure the stack gas velocity pressure
- A 316 stainless steel connector to connect the outlet of the probe to the inlet of the impinger train
- An impinger train containing 3 impingers, 2 traps, and 1 impinger in series (No. 1 -- 200 ml distilled water; No. 2 -- 200 ml distilled water; No. 3 -- dry; a 10-cm long glass trap, 2.2 cm I.D. packed with 30/60 mesh Grade A Florisil®, a 10 cm long glass trap, 2.2 cm I.D. packed with 30/60 mesh XAD-2; No. 4 -- 200 gm silica gel)
- A vacuum hose to connect the outlet of the impinger train to a vacuum pump
- A 10-cfm carbon vane vacuum pump modified for low leakage around the shaft
- A vacuum hose to connect the pump outlet to the control module
- A control module to measure the temperature, pressure, flowrate and gas volume of the sampled gases

The material collected in this entire sampling train was analyzed for PCB and RCℓ.

3.2.2.3 $NO_x$ Sampling Equipment. The $NO_x$ sampling train used during the trial burn conformed to the equipment specified in EPA Method 7 and consisted of the following components:

- A heated, 5-ft glass-lined probe with a plug of glass wool to remove particulates
- A 2-liter glass flask with a thermowell to measure flask temperature
- A three-way flask valve to purge the probe, evacuate the flask and draw a sample of gas
- A 36-in. U-tube manometer to measure the vacuum in the flask
- A vacuum pump to evacuate the flask to 3 in. Hg absolute

Each flask contained the acidified peroxide absorption solution specified to collect $NO_x$.

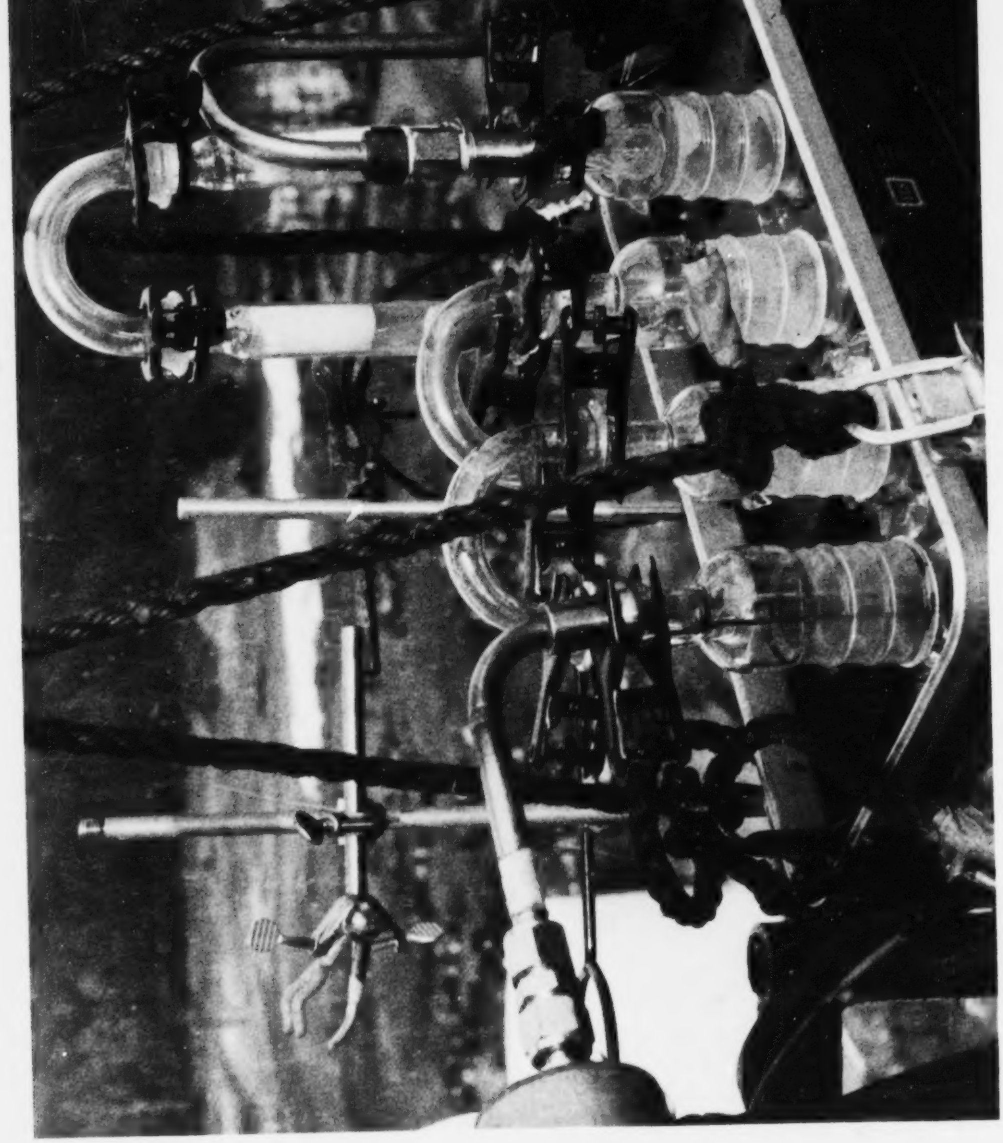

Figure 3-8. PCB/RCℓ Impinger Train

3.2.2.4 CO, $CO_2$, $O_2$ Sampling Equipment. The fixed gases sampling train was assembled in accordance with EPA Method 3 and consisted of the following components:

- A stainless steel probe with a plug of glass wool to remove particulates
- An air cooled condenser to remove moisture from the sampled gases
- A teflon lined diaphragm pump to draw a sample of the gases
- A Tedlar® bag to contain the sample of stack gases

An Orsat analyzer was used to analyze the contents of the Tedlar® bag for CO, $CO_2$ and $O_2$.

## 3.3 SAMPLING PROCEDURES

The procedures used to sample the various input and output streams from the ENSCO facility are described in this section.

### 3.3.1 Process Stream Sampling Procedures

All liquid process streams (liquid organic waste, well water, recycled scrubber liquor, scrubber liquor, lime slurry and caustic solution) were sampled in the same manner. First, each line and each valve which was used to extract a liquid sample was flushed for several seconds to remove any previous liquid. The sample container (a clean 500-ml amber glass jar) was then flushed twice with the liquid to be sampled. A 500-ml sample of the liquid was then collected and immediately transferred to a 1-gal compositing jug. Each liquid stream had its own sampling jar and compositing jug which were sealed with teflon-lined caps when not in use. Each liquid stream was sampled every 30 minutes during each test. At the conclusion of the test, the compositing jug was sealed, labelled and prepared for shipment to Mountain View for analysis.

The rotary kiln ash was sampled in a similar manner. Samples of the kiln ash were collected in a clean 1-qt steel can every 30 minutes. The can was filled and emptied twice and then a sample was taken. This sample was immediately transferred to the 20-gal compositing can. At the end of a test, a clean stainless steel rod was used to thoroughly mix the composite sample in the 20-gal compositing can. A 250-ml sample of the thoroughly mixed ash was collected in an amber glass jar which was sealed, labelled and prepared for shipment.

The shredded capacitor stream and the liquid PCB stream were sampled directly with the 1-qt cans every 15 to 30 minutes.

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### 3.3.2 Stack Sampling Procedures

The following paragraphs and flow charts summarize the procedures used to sample the stack gases.

3.3.2.1 Particulate Matter and Hydrochloric Acid Sampling Procedures. Figures 3-9, 3-10, and 3-11 illustrate the procedures used to prepare the particulate matter/HCℓ sampling train prior to a test, the procedures used to sample the stack gases and the procedures used to recover the sample from the train. All procedures were in accordance with EPA Method 5. All tests were 1 hour in length and exceeded the minimum volume of gas sampled (30 $ft^3$). All tests were done isokinetically.

3.3.2.2 PCB and RCℓ Sampling Procedures. Figures 3-12, 3-13 and 3-14 depict the procedures used for the PCB/RCℓ sampling train. The sampling rate during each test was isokinetic and never exceeded the maximum rate of 0.75 cfm specified by the test method. The sampling test time was 4 hours which was the maximum time recommended. At no time during a test was any train disassembled (except for condensate removal and leak check). Finally, for each series of tests a blank train was set up, sealed for the duration of the test, and recovered as indicated in Figure 3-14. The purpose of this blank train was to determine whether or not the train was contaminated during setup and takedown on the stack.

3.3.2.3 $NO_x$ Sampling Procedures. Figures 3-15, 3-16 and 3-17 summarize the procedures used to conduct the $NO_x$ tests. All tests were conducted in accordance with EPA Method 7.

3.3.2.4 CO, $CO_2$, $O_2$ Sampling Procedures. Figure 3-18 illustrates the procedure used to measure the CO, $CO_2$ and $O_2$ content of the stack gases. No special preparations were required apart from making sure the Tedlar® bag was leak free and the Orsat was filled with fresh reagents.

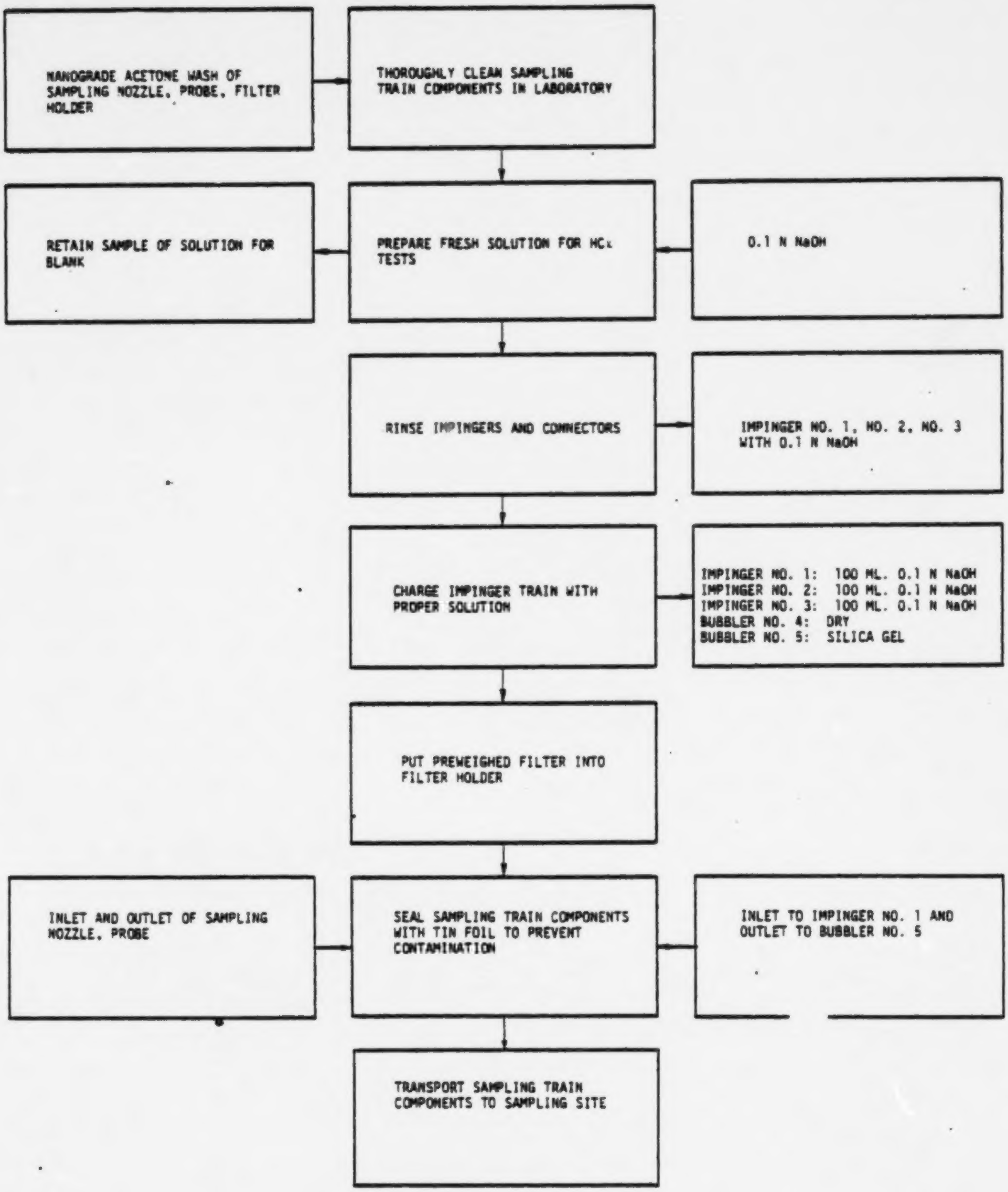
NANOGRADE ACETONE WASH OF SAMPLING NOZZLE, PROBE, FILTER HOLDER
THOROUGHLY CLEAN SAMPLING TRAIN COMPONENTS IN LABORATORY
RETAIN SAMPLE OF SOLUTION FOR BLANK
PREPARE FRESH SOLUTION FOR HCℓ TESTS
0.1 N NaOH
RINSE IMPINGERS AND CONNECTORS
IMPINGER NO. 1, NO. 2, NO. 3 WITH 0.1 N NaOH
CHARGE IMPINGER TRAIN WITH PROPER SOLUTION
IMPINGER NO. 1: 100 ML. 0.1 N NaOH
IMPINGER NO. 2: 100 ML. 0.1 N NaOH
IMPINGER NO. 3: 100 ML. 0.1 N NaOH
BUBBLER NO. 4: DRY
BUBBLER NO. 5: SILICA GEL
PUT PREWEIGHED FILTER INTO FILTER HOLDER
INLET AND OUTLET OF SAMPLING NOZZLE, PROBE
SEAL SAMPLING TRAIN COMPONENTS WITH TIN FOIL TO PREVENT CONTAMINATION
INLET TO IMPINGER NO. 1 AND OUTLET TO BUBBLER NO. 5
TRANSPORT SAMPLING TRAIN COMPONENTS TO SAMPLING SITE

Figure 3-9. Preparation Procedures for Particulate/HCℓ Sampling Train

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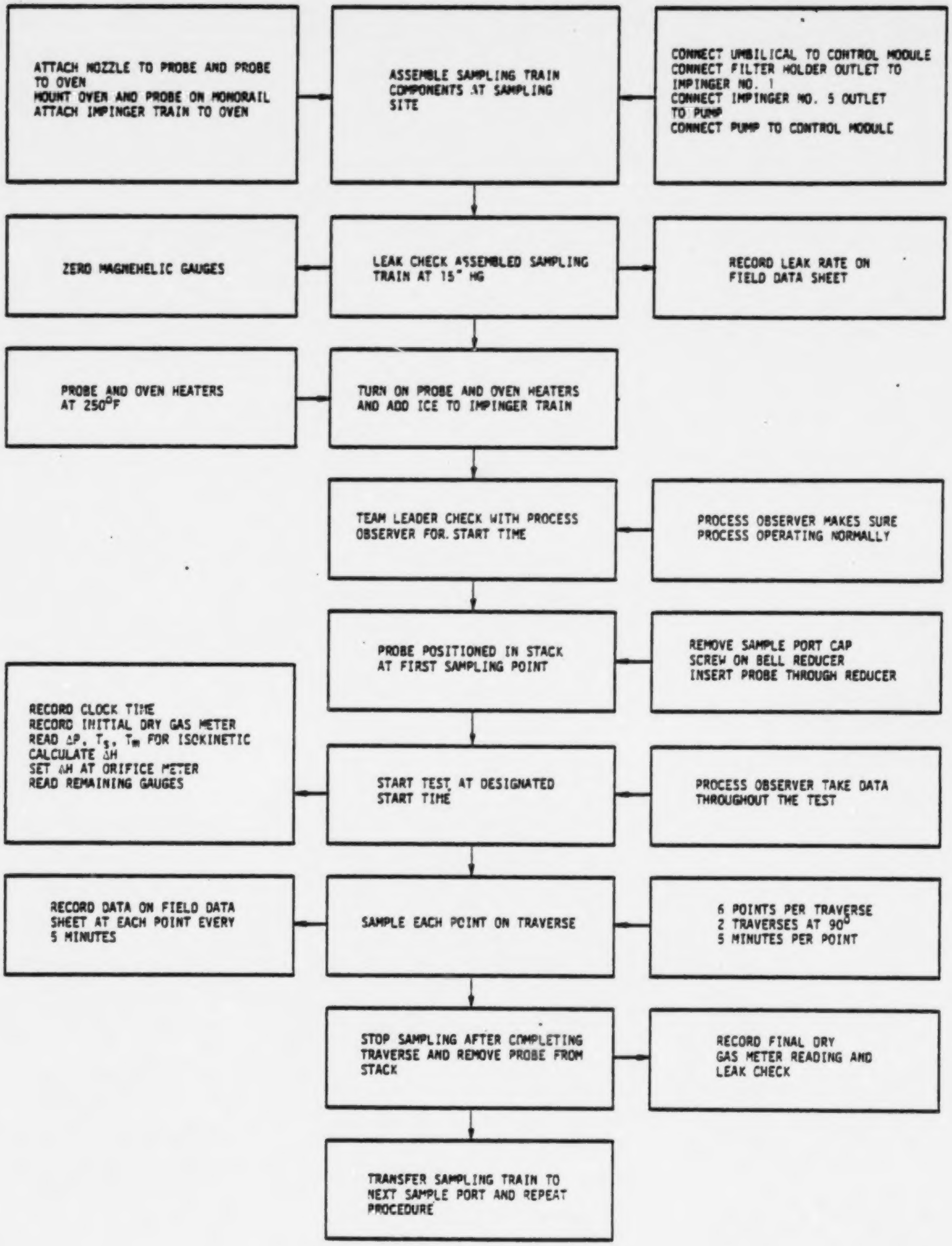
ATTACH NOZZLE TO PROBE AND PROBE TO OVEN
MOUNT OVEN AND PROBE ON MONORAIL
ATTACH IMPINGER TRAIN TO OVEN
ASSEMBLE SAMPLING TRAIN COMPONENTS AT SAMPLING SITE
CONNECT UMBILICAL TO CONTROL MODULE
CONNECT FILTER HOLDER OUTLET TO IMPINGER NO. 1
CONNECT IMPINGER NO. 5 OUTLET TO PUMP
CONNECT PUMP TO CONTROL MODULE
ZERO MAGNEHELIC GAUGES
LEAK CHECK ASSEMBLED SAMPLING TRAIN AT 15" HG
RECORD LEAK RATE ON FIELD DATA SHEET
PROBE AND OVEN HEATERS AT 250°F
TURN ON PROBE AND OVEN HEATERS AND ADD ICE TO IMPINGER TRAIN
TEAM LEADER CHECK WITH PROCESS OBSERVER FOR START TIME
PROCESS OBSERVER MAKES SURE PROCESS OPERATING NORMALLY
PROBE POSITIONED IN STACK AT FIRST SAMPLING POINT
REMOVE SAMPLE PORT CAP
SCREW ON BELL REDUCER
INSERT PROBE THROUGH REDUCER
RECORD CLOCK TIME
RECORD INITIAL DRY GAS METER
READ ΔP, $T_s$, $T_m$ FOR ISOKINETIC
CALCULATE ΔH
SET ΔH AT ORIFICE METER
READ REMAINING GAUGES
START TEST AT DESIGNATED START TIME
PROCESS OBSERVER TAKE DATA THROUGHOUT THE TEST
RECORD DATA ON FIELD DATA SHEET AT EACH POINT EVERY 5 MINUTES
SAMPLE EACH POINT ON TRAVERSE
6 POINTS PER TRAVERSE
2 TRAVERSES AT 90°
5 MINUTES PER POINT
STOP SAMPLING AFTER COMPLETING TRAVERSE AND REMOVE PROBE FROM STACK
RECORD FINAL DRY GAS METER READING AND LEAK CHECK
TRANSFER SAMPLING TRAIN TO NEXT SAMPLE PORT AND REPEAT PROCEDURE

Figure 3-10. Sampling Procedures for Particulate/HCℓ Sampling Train

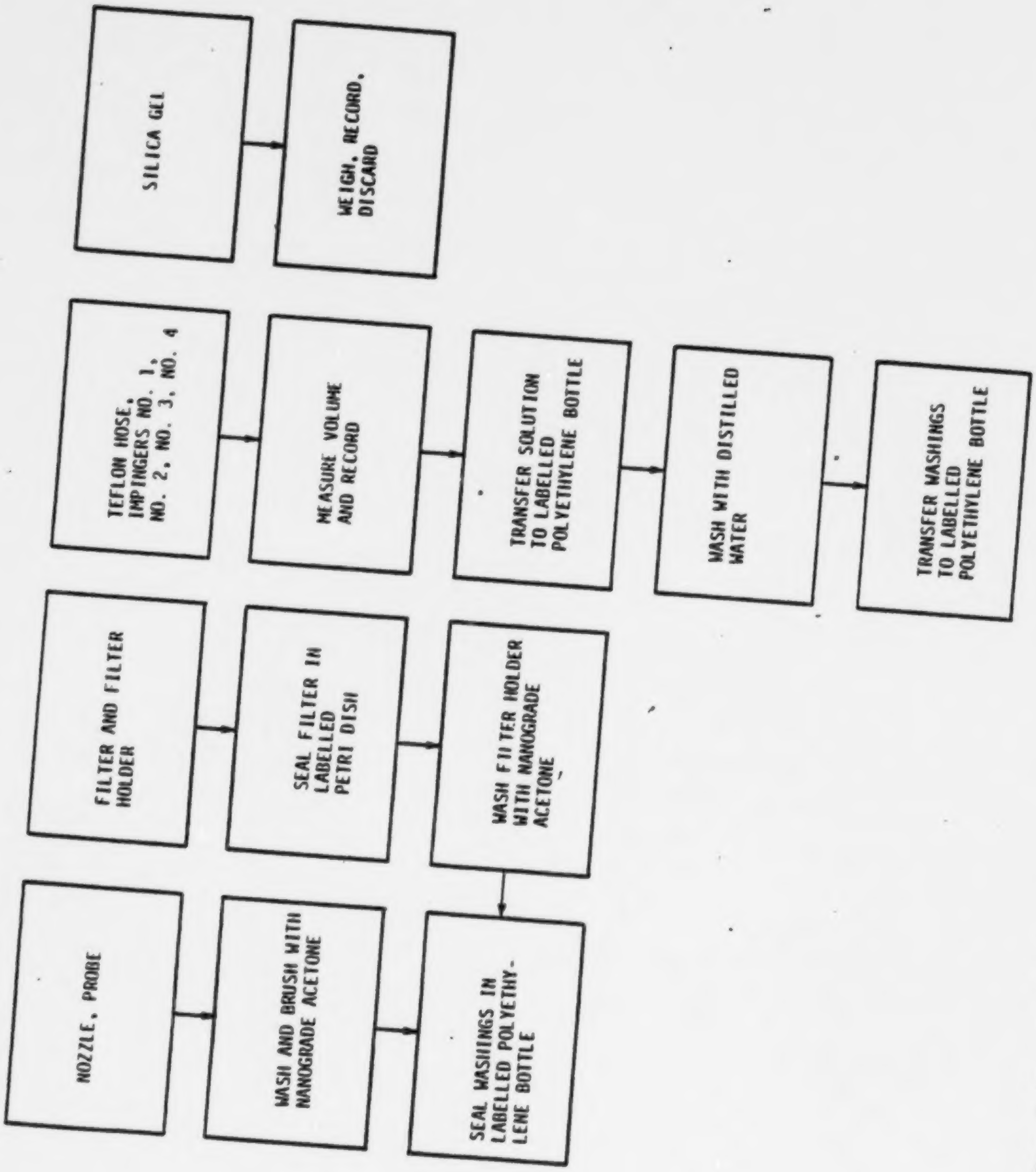
NOZZLE, PROBE
WASH AND BRUSH WITH NANOGRADE ACETONE
SEAL WASHINGS IN LABELLED POLYETHYLENE BOTTLE
FILTER AND FILTER HOLDER
SEAL FILTER IN LABELLED PETRI DISH
WASH FILTER HOLDER WITH NANOGRADE ACETONE
TEFLON HOSE, IMPINGERS NO. 1, NO. 2, NO. 3, NO. 4
MEASURE VOLUME AND RECORD
TRANSFER SOLUTION TO LABELLED POLYETHYLENE BOTTLE
WASH WITH DISTILLED WATER
TRANSFER WASHINGS TO LABELLED POLYETHYLENE BOTTLE
SILICA GEL
WEIGH, RECORD, DISCARD

Figure 3-11. Sample Recovery Procedures for Particulate/HCℓ

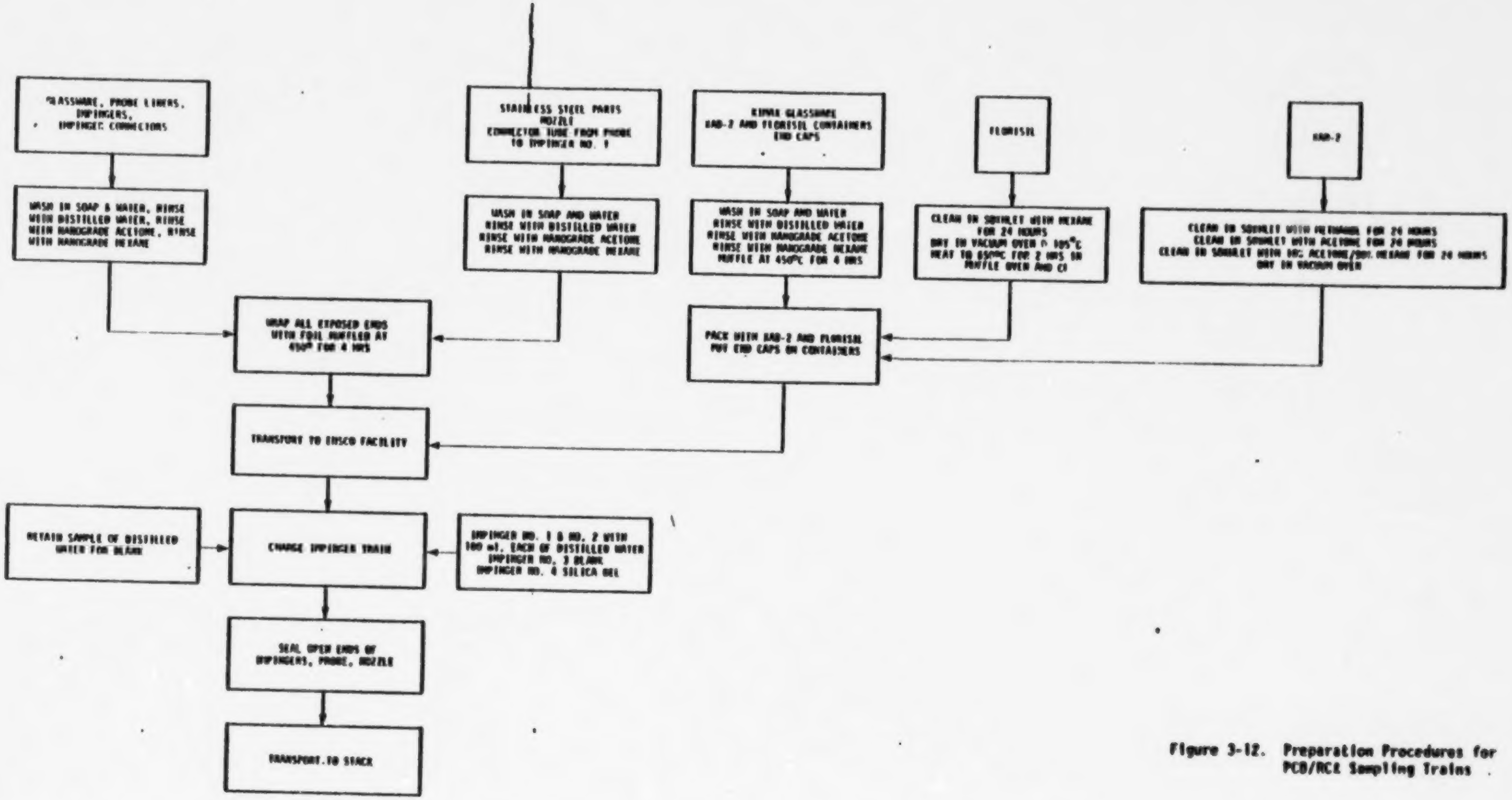
GLASSWARE, PROBE LINERS, IMPINGERS, IMPINGER CONNECTORS
WASH IN SOAP & WATER, RINSE WITH DISTILLED WATER, RINSE WITH NANOGRADE ACETONE, RINSE WITH NANOGRADE HEXANE
STAINLESS STEEL PARTS NOZZLE CONNECTOR TUBE FROM PROBE TO IMPINGER NO. 1
WASH IN SOAP AND WATER RINSE WITH DISTILLED WATER RINSE WITH NANOGRADE ACETONE RINSE WITH NANOGRADE HEXANE
KIMAX GLASSWARE XAD-2 AND FLORISIL CONTAINERS END CAPS
WASH IN SOAP AND WATER RINSE WITH DISTILLED WATER RINSE WITH NANOGRADE ACETONE RINSE WITH NANOGRADE HEXANE MUFFLE AT 450°C FOR 4 HRS
FLORISIL
CLEAN IN SOXHLET WITH HEXANE FOR 24 HOURS DRY IN VACUUM OVEN @ 105°C HEAT TO 650°C FOR 2 HRS IN MUFFLE OVEN AND CI
XAD-2
CLEAN IN SOXHLET WITH METHANOL FOR 24 HOURS CLEAN IN SOXHLET WITH ACETONE FOR 24 HOURS CLEAN IN SOXHLET WITH 10% ACETONE/90% HEXANE FOR 24 HOURS DRY IN VACUUM OVEN
WRAP ALL EXPOSED ENDS WITH FOIL MUFFLED AT 450° FOR 4 HRS
PACK WITH XAD-2 AND FLORISIL PUT END CAPS ON CONTAINERS
TRANSPORT TO ENSCO FACILITY
RETAIN SAMPLE OF DISTILLED WATER FOR BLANK
CHARGE IMPINGER TRAIN
IMPINGER NO. 1 & NO. 2 WITH 100 ml. EACH OF DISTILLED WATER IMPINGER NO. 3 BLANK IMPINGER NO. 4 SILICA GEL
SEAL OPEN ENDS OF IMPINGERS, PROBE, NOZZLE
TRANSPORT TO STACK

Figure 3-12. Preparation Procedures for PCB/RCE Sampling Trains

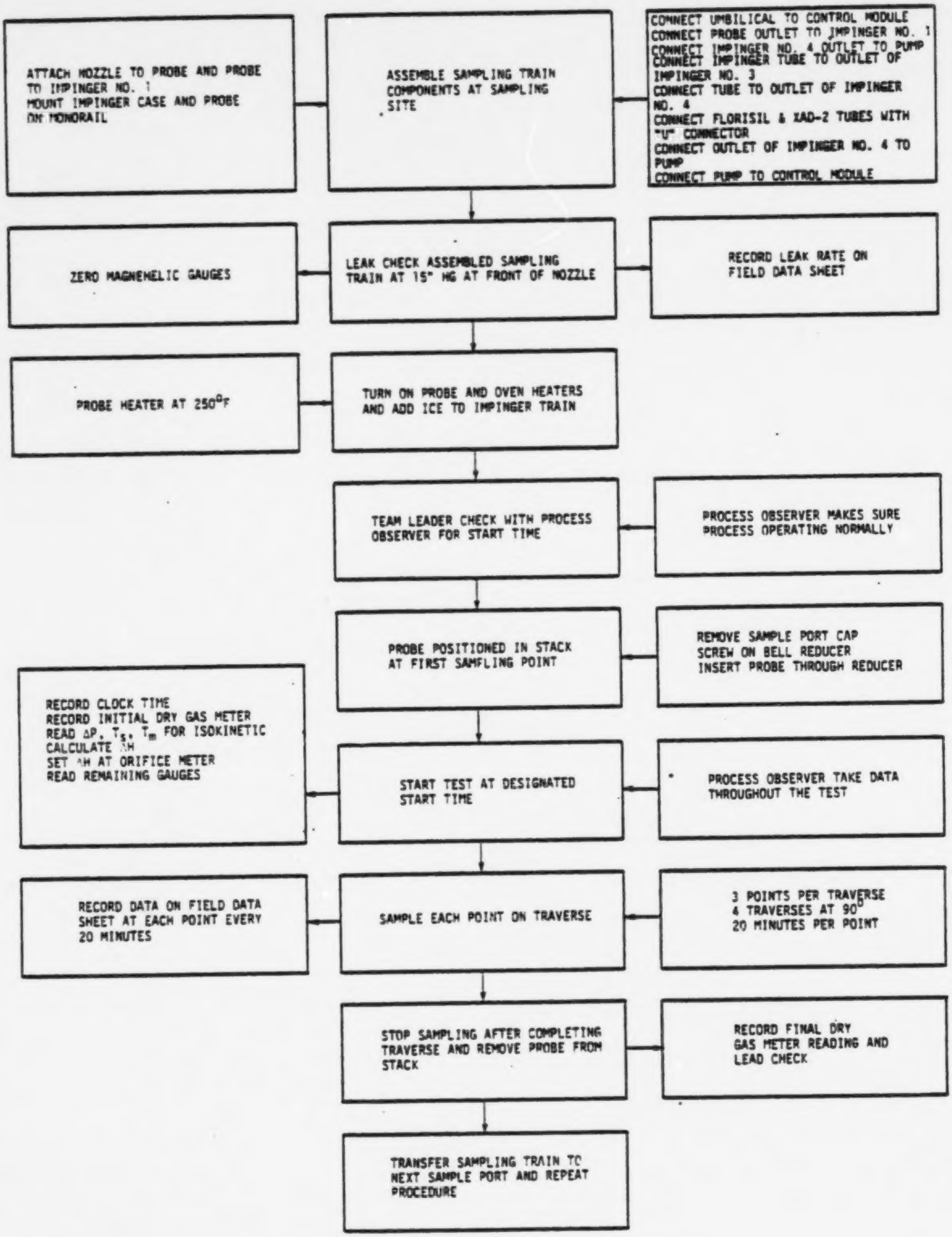
ATTACH NOZZLE TO PROBE AND PROBE TO IMPINGER NO. 1
MOUNT IMPINGER CASE AND PROBE ON MONORAIL
ASSEMBLE SAMPLING TRAIN COMPONENTS AT SAMPLING SITE
CONNECT UMBILICAL TO CONTROL MODULE
CONNECT PROBE OUTLET TO IMPINGER NO. 1
CONNECT IMPINGER NO. 4 OUTLET TO PUMP
CONNECT IMPINGER TUBE TO OUTLET OF IMPINGER NO. 3
CONNECT TUBE TO OUTLET OF IMPINGER NO. 4
CONNECT FLORISIL & XAD-2 TUBES WITH "U" CONNECTOR
CONNECT OUTLET OF IMPINGER NO. 4 TO PUMP
CONNECT PUMP TO CONTROL MODULE
ZERO MAGNEHELIC GAUGES
LEAK CHECK ASSEMBLED SAMPLING TRAIN AT 15" HG AT FRONT OF NOZZLE
RECORD LEAK RATE ON FIELD DATA SHEET
PROBE HEATER AT 250°F
TURN ON PROBE AND OVEN HEATERS AND ADD ICE TO IMPINGER TRAIN
TEAM LEADER CHECK WITH PROCESS OBSERVER FOR START TIME
PROCESS OBSERVER MAKES SURE PROCESS OPERATING NORMALLY
PROBE POSITIONED IN STACK AT FIRST SAMPLING POINT
REMOVE SAMPLE PORT CAP
SCREW ON BELL REDUCER
INSERT PROBE THROUGH REDUCER
RECORD CLOCK TIME
RECORD INITIAL DRY GAS METER
READ ΔP, T$_s$, T$_m$ FOR ISOKINETIC
CALCULATE ΔH
SET ΔH AT ORIFICE METER
READ REMAINING GAUGES
START TEST AT DESIGNATED START TIME
PROCESS OBSERVER TAKE DATA THROUGHOUT THE TEST
RECORD DATA ON FIELD DATA SHEET AT EACH POINT EVERY 20 MINUTES
SAMPLE EACH POINT ON TRAVERSE
3 POINTS PER TRAVERSE
4 TRAVERSES AT 90°
20 MINUTES PER POINT
STOP SAMPLING AFTER COMPLETING TRAVERSE AND REMOVE PROBE FROM STACK
RECORD FINAL DRY GAS METER READING AND LEAD CHECK
TRANSFER SAMPLING TRAIN TO NEXT SAMPLE PORT AND REPEAT PROCEDURE

Figure 3-13. Sampling Procedures for PCB/RCℓ Sampling Train

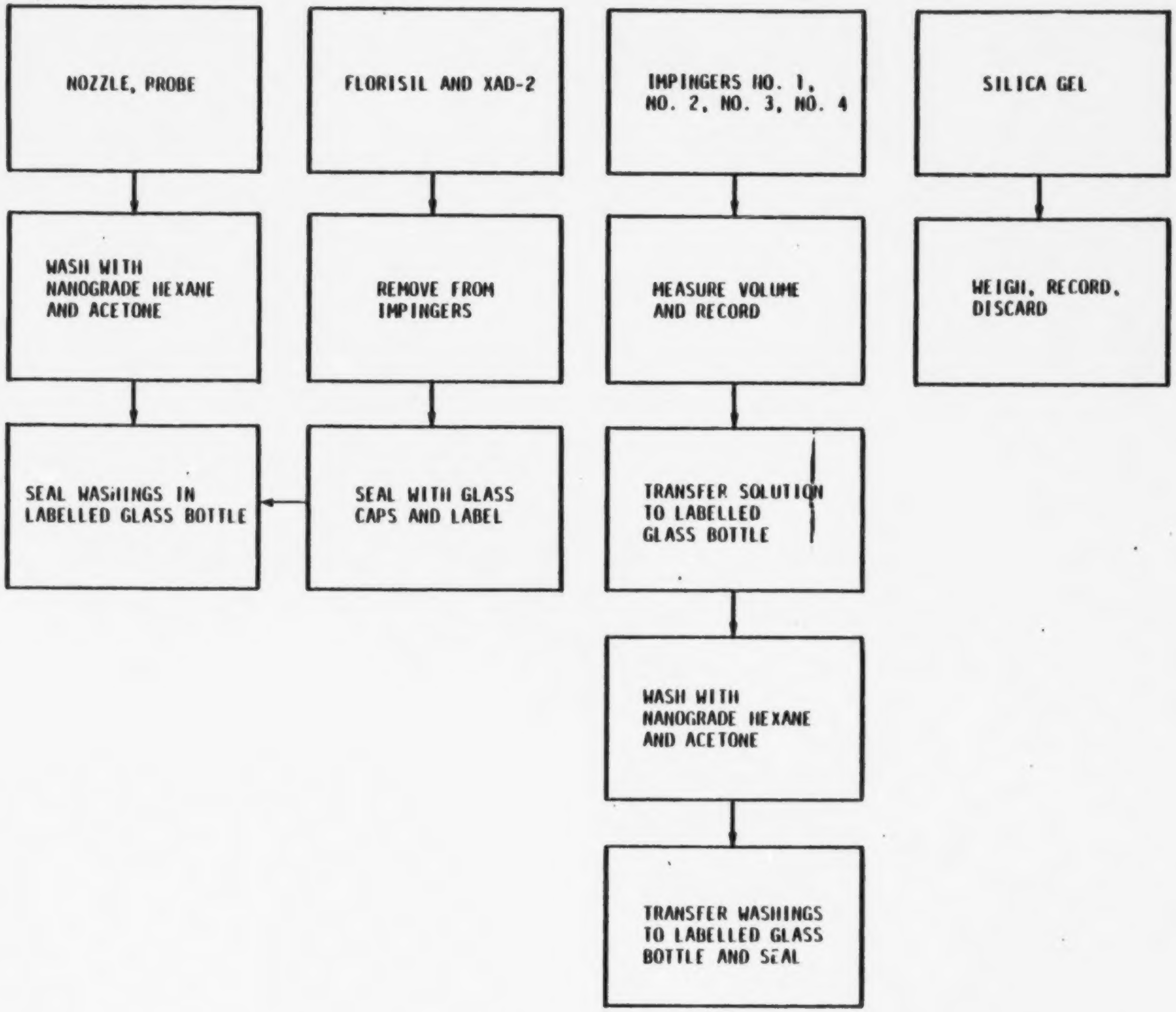
NOZZLE, PROBE
WASH WITH NANOGRADE HEXANE AND ACETONE
SEAL WASHINGS IN LABELLED GLASS BOTTLE
FLORISIL AND XAD-2
REMOVE FROM IMPINGERS
SEAL WITH GLASS CAPS AND LABEL
IMPINGERS NO. 1, NO. 2, NO. 3, NO. 4
MEASURE VOLUME AND RECORD
TRANSFER SOLUTION TO LABELLED GLASS BOTTLE
WASH WITH NANOGRADE HEXANE AND ACETONE
TRANSFER WASHINGS TO LABELLED GLASS BOTTLE AND SEAL
SILICA GEL
WEIGH, RECORD, DISCARD

Figure 3-14. Sample Recovery Procedures for PCB/RCℓ Sampling Train

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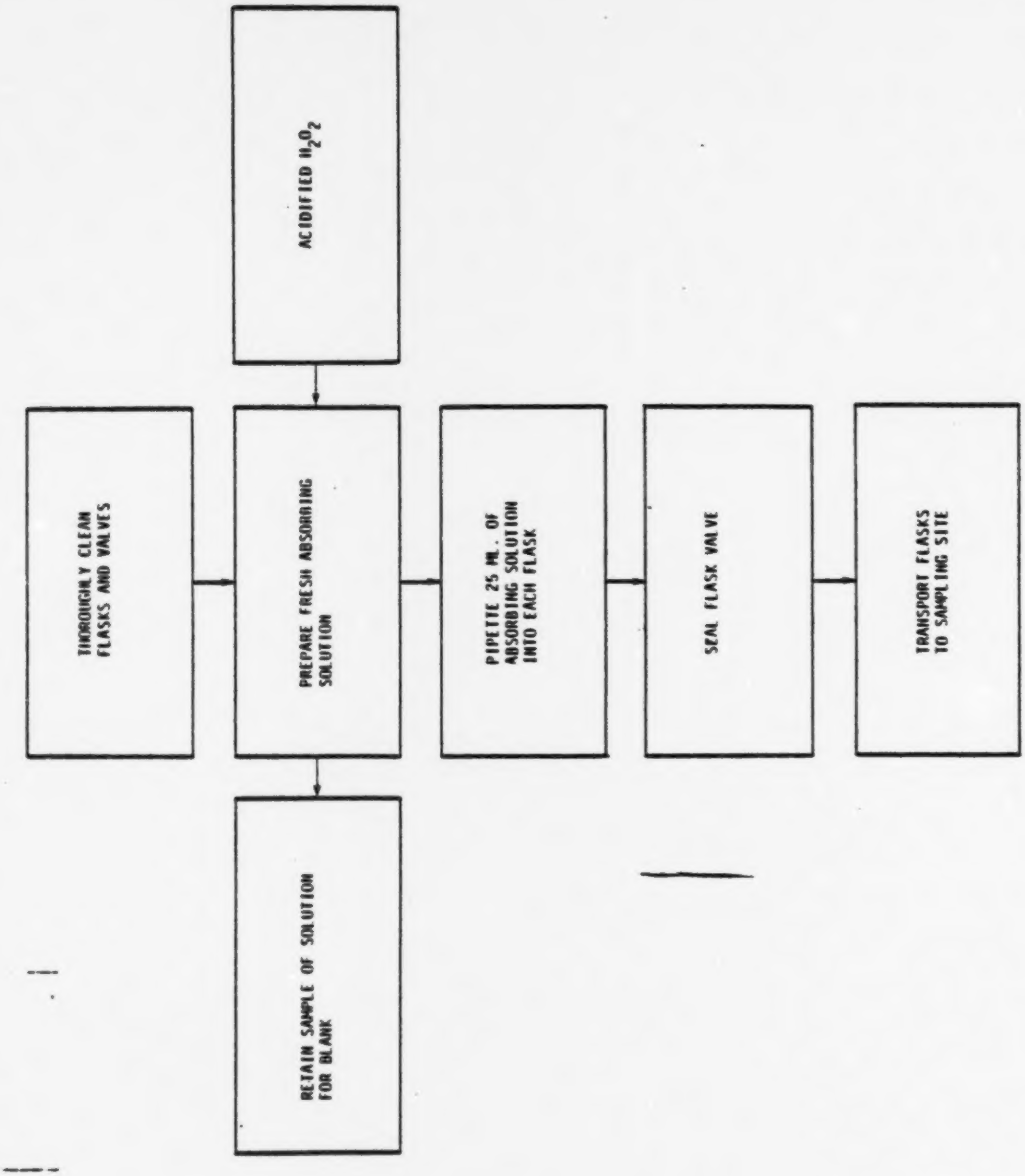

ACIDIFIED $H_2O_2$
THOROUGHLY CLEAN FLASKS AND VALVES
PREPARE FRESH ABSORBING SOLUTION
PIPETTE 25 ML. OF ABSORBING SOLUTION INTO EACH FLASK
SEAL FLASK VALVE
TRANSPORT FLASKS TO SAMPLING SITE
RETAIN SAMPLE OF SOLUTION FOR BLANK

Figure 3-15. Preparation Procedures for $NO_x$ Sampling Train

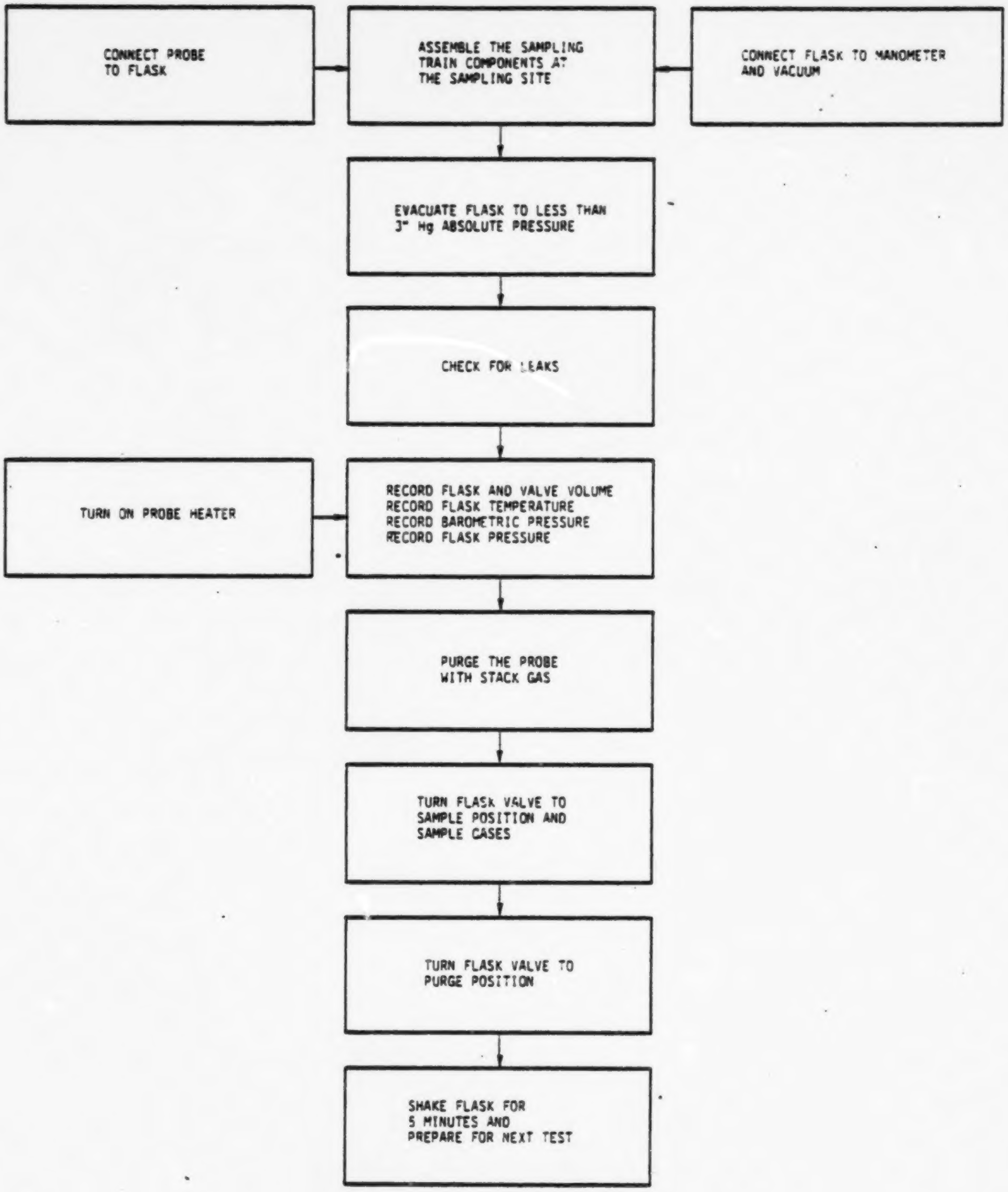

CONNECT PROBE TO FLASK
ASSEMBLE THE SAMPLING TRAIN COMPONENTS AT THE SAMPLING SITE
CONNECT FLASK TO MANOMETER AND VACUUM
EVACUATE FLASK TO LESS THAN 3" Hg ABSOLUTE PRESSURE
CHECK FOR LEAKS
TURN ON PROBE HEATER
RECORD FLASK AND VALVE VOLUME
RECORD FLASK TEMPERATURE
RECORD BAROMETRIC PRESSURE
RECORD FLASK PRESSURE
PURGE THE PROBE WITH STACK GAS
TURN FLASK VALVE TO SAMPLE POSITION AND SAMPLE CASES
TURN FLASK VALVE TO PURGE POSITION
SHAKE FLASK FOR 5 MINUTES AND PREPARE FOR NEXT TEST

Figure 3-16. Sampling Procedures for $NO_x$

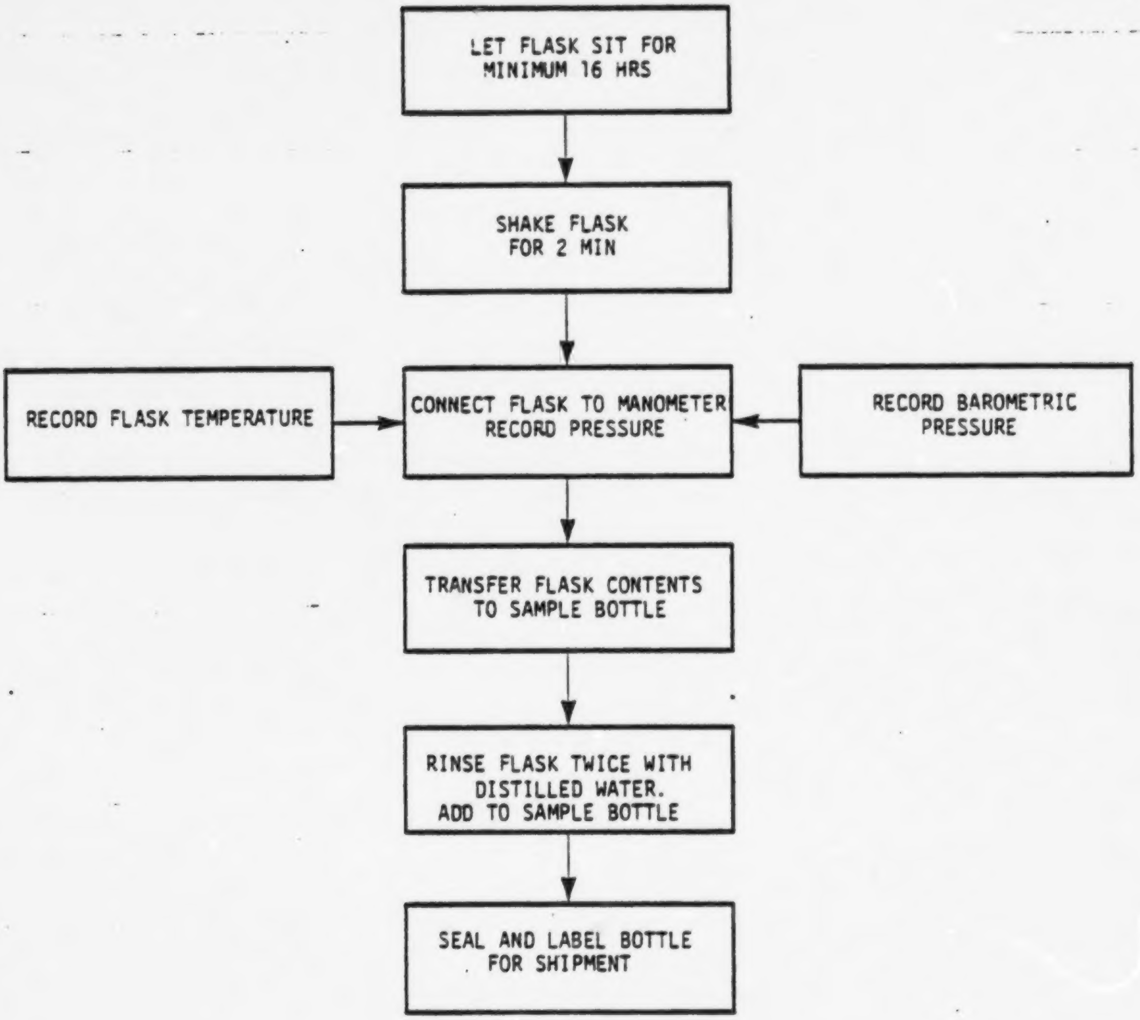

LET FLASK SIT FOR MINIMUM 16 HRS
SHAKE FLASK FOR 2 MIN
RECORD FLASK TEMPERATURE
CONNECT FLASK TO MANOMETER RECORD PRESSURE
RECORD BAROMETRIC PRESSURE
TRANSFER FLASK CONTENTS TO SAMPLE BOTTLE
RINSE FLASK TWICE WITH DISTILLED WATER. ADD TO SAMPLE BOTTLE
SEAL AND LABEL BOTTLE FOR SHIPMENT

Figure 3-17. Sample Recovery Procedures for $NO_x$

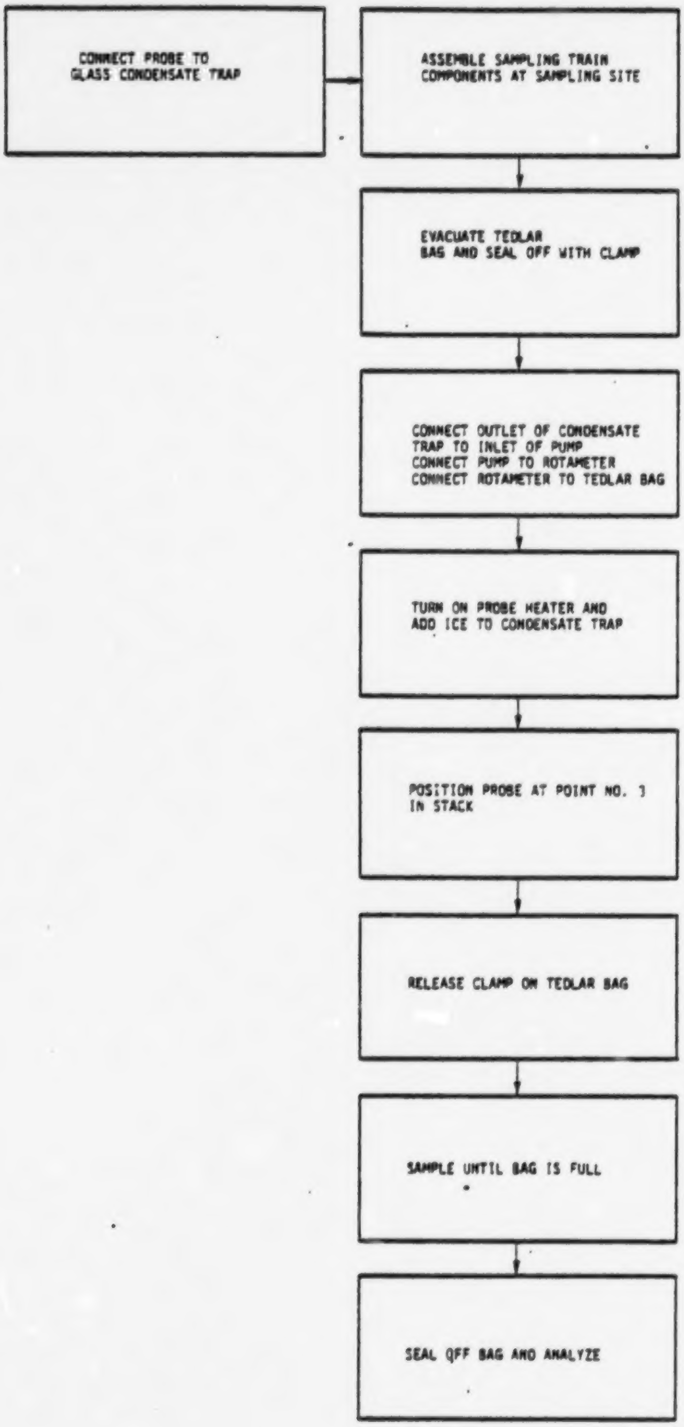

CONNECT PROBE TO
GLASS CONDENSATE TRAP
ASSEMBLE SAMPLING TRAIN
COMPONENTS AT SAMPLING SITE
EVACUATE TEDLAR
BAG AND SEAL OFF WITH CLAMP
CONNECT OUTLET OF CONDENSATE
TRAP TO INLET OF PUMP
CONNECT PUMP TO ROTAMETER
CONNECT ROTAMETER TO TEDLAR BAG
TURN ON PROBE HEATER AND
ADD ICE TO CONDENSATE TRAP
POSITION PROBE AT POINT NO. 1
IN STACK
RELEASE CLAMP ON TEDLAR BAG
SAMPLE UNTIL BAG IS FULL
SEAL OFF BAG AND ANALYZE

Figure 3-18. Sampling Procedures for $CO_2$, $O_2$, CO

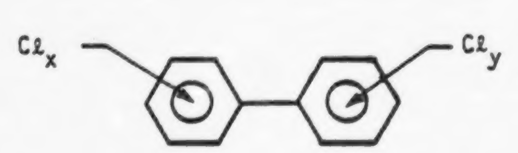
## SECTION 4

## ANALYTICAL PROCEDURES AND RESULTS

This section of the report details the procedures used to analyze the samples collected during the PCB trial burn and discusses the results of these analyses in detail.

### 4.1 INTRODUCTORY AND GENERAL APPROACH

PCBs are a complex family of compounds and isomers (Figure 4-1) (1). Aroclors are mixtures of PCBs defined by the average number of chlorine atoms per molecule and isolated by boiling point range. A common analytical procedure utilizes recognition of unique gas chromatographic patterns for given Aroclors. Industrial treatment such as heating, mixing with other materials, or environmental aging (weathering) can change the isomeric distribution of a given Aroclor. Using pattern recognition to identify given Aroclors can be a formidable task. To overcome this problem, the compounds can be perchlorinated to decachlorobiphenyl (DCB) (x and y in Figure 4-1 both equal 5). Biphenyl (the carbon skeleton of PCBs without any chlorines) will also be chlorinated and must be determined independently. These considerations determined the analytical approach to the samples analyzed for this project.



$x = 0 - 5$

$y = 0 - 5$

Figure 4-1. General Formula for Polychlorinated Biphenyls.

Quantitative analysis of PCBs presents a unique challenge for the analytical chemist. There are 209 potential PCB compounds and isomers, each one having its own chromatographic properties. The formidable problem of quantitation has been limited to three discrete methods. This section describes these methods and discusses some of the advantages and disadvantages of each.

The three methods used for quantitation are:

- Pattern recognition
- Derivatization
- Measurement of individual PCB components

### 4.1.1 Pattern Recognition

PCB mixtures (known as Aroclors in the United States) are formulated for different industrial purposes. A fortunate coincidence of this production phenomena is the gas chromatographic profile of the different formulations. Each of the Aroclor mixtures, when analyzed by gas chromatography, has a unique elution pattern. This observation has led to an analytical technique known as pattern recognition. Pattern recognition, described in detail by Hutzinger (1) affords the following advantages:

- Identification of the Aroclor mixture which may in turn help localize the source of environmental contamination
- May be accomplished by the use of relatively simple, nonexpensive gas chromatographic equipment
- Has the potential of low artifact production, which enables more accurate quantitation if the samples are relatively "clean"

Pattern recognition has become an established technique. The analytical chemist, however, must be aware that this method has definite disadvantages when applied to certain types of samples. Samples derived from combustion products and environmental samples that have undergone "weathering" may not be amenable to pattern recognition techniques. Samples containing chlorinated pesticides or mixtures of Aroclors may also pose a problem when accurate quantitation is necessary. These compounds have the same extraction characteristics as PCBs, and may co-chromatograph with PCBs, altering the Aroclor pattern and frustrating pattern recognition and quantitation.

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The disadvantages may be summarized as follows:

- Samples from combustion products and "weathered" samples may have undergone chemical changes and pattern alterations, thus obscuring efforts to use patterns for Aroclor number assignments
- Because of interferences from other sources the quantitation of PCBs is subject to significant error

### 4.1.2 Derivatization

Derivatization theoretically simplifies the analysis of PCBs by converting all 209 homologs to a single chromatographable species. The compound formed, DCB, is a fully chlorine-substituted biphenyl that is prepared by a reaction involving antimony pentachloride. The perchlorination technique, originally proposed by Berg and later by Armour (2), has been used with success and has inherent advantages.

- Lowers the detection limit of the analysis
- Gives a "cleaner" analysis by conversion of PCB homologs to one species
- Yields unequivical quantitation of DCB

As the title of the Armour paper suggests and the text reinforces, this procedure should be used only as a confirmation technique and the quantitative accuracy of the procedure is highly dependent on the test sample PCB mixture. Correction factors for DCB analysis, to convert back to the original weight of PCB present, may range from approximately 0.4 for Aroclor 1221 to 0.80 for Aroclor 1260.

The factor cannot be known precisely without accurate knowledge of the actual homolog distribution within the original perchlorinated sample. There is a large weight change in the conversion of PCBs to DCB. This large weight change is caused by the addition of chlorine atoms to the precursor PCB homolog molecule. The number of chlorine atoms added is, of course, dependent upon which homolog is being derivatized and the original number of chlorines present in the molecule. Thus a reported DCB number could be twice as high as the actual PCB level present.

Samples obtained from combustion sources will definitely have homolog distribution changes when compared with the profile of the original feed material. These distribution changes make it impossible to estimate the actual contribution from real chlorinated biphenyls by a factor of any less than two.

Additional errors that may be incorporated into the derivatization process include artifact DCB production. Haile (3) has documented DCB methodology applied to combustion sources that resulted in false positives. Confirmation of PCB in a duplicate, nonperchlorinated aliquot suggested that the DCB measured in the sample was an artifact of non-PCB combustion products. To date, no confirmed explanation of the origin of this artifact has been presented.

The DCB methodology will, in all cases, overestimate the sample concentration of PCB. This fact should be recognized and experimental design should be approached with regards to correction mechanisms to reflect real PCB levels.

### 4.1.3 Measurement of Individual PCB Components

A third approach used to quantitate PCB materials avoids the errors intrinsic to both derivatization and pattern recognition. This method, proposed by Webb and McCall (4) was partially incorporated into the Federal Register and was recommended for use when pattern recognition seemed to be nonapplicable. Additional work published by Eichelberger, Harris and Budde (5) laid the groundwork for an alternate approach using GC/MS. A detailed explanation of this methodology has been published in EPA Report 600/7-79-047 entitled "Measurement of PCB Emissions from Combustion Sources."

Briefly, the method measures each PCB peak, determines the number of chlorines in the compound representing the peak, then applies a response factor derived from a PCB having the same number of chlorine substituents to that peak. This procedure is applied consecutively to each PCB peak in a sample chromatogram and the resultant weights are summed yielding the total weight of PCB in the sample injection. The use of GC/MS analysis with this methodology results in the most accurate determination of PCB levels. The current availability of capillary gas chromatographic systems that are interfaced directly into the mass spectrometer promises to update the state-of-the-art for PCB analysis.

Capillary gas chromatographic systems are generally characterized as more sensitive than packed column systems and possess far better resolution. The combination of these factors, when used with mass spectrometry should, in theory, be the most accurate quantitation procedure available.

Advantages of the measurement of individual PCB components method are as follows:

- Accuracy does not depend on correct identification of Aroclor by pattern recognition; therefore, weathered samples and samples derived from combustion sources may be quantitated as accurately as pure standards

- Eliminates the potential for false positive identifications that would occur as a result of perchlorination

Disadvantages

- Ultimate accuracy will be achieved only by use of GC/MS which is expensive and requires highly trained staff

- Overall detection limits are higher than DCB and GC methodologies

- Requires numerous standards for determining response factors

- Requires extensive data reduction

The quantitation procedure for PCBs by perchlorination, as recommended by EPA (6), was developed by Armour for detection of PCB residues in biological materials. To achieve accurate numbers, the actual percent chlorine in the particular PCB mixture must be known. A close approximation can be obtained if a particular commercial mixture pattern can be identified. Prior to the development of the perchlorination procedure, pattern recognition and integration of multiple GC peaks by various formulas was the preferred method to quantitate PCBs. These methods have the common analytical problems associated with determining response factors, integration of peaks, potential for overlapping peaks from compounds of no interest, and the problem of changing isomer ratios caused by environmental factors.

It was then decided to use the DCB methodology to determine the potential presence and approximate quantity of PCBs, and to verify the presence of PCBs by GC/MS identification of specific isomers.

The general analytical approach (Figure 4-2) was to:

- Extract the organic fraction from a given sample

- Perchlorinate a portion of the raw extract

- Analyze for DCB

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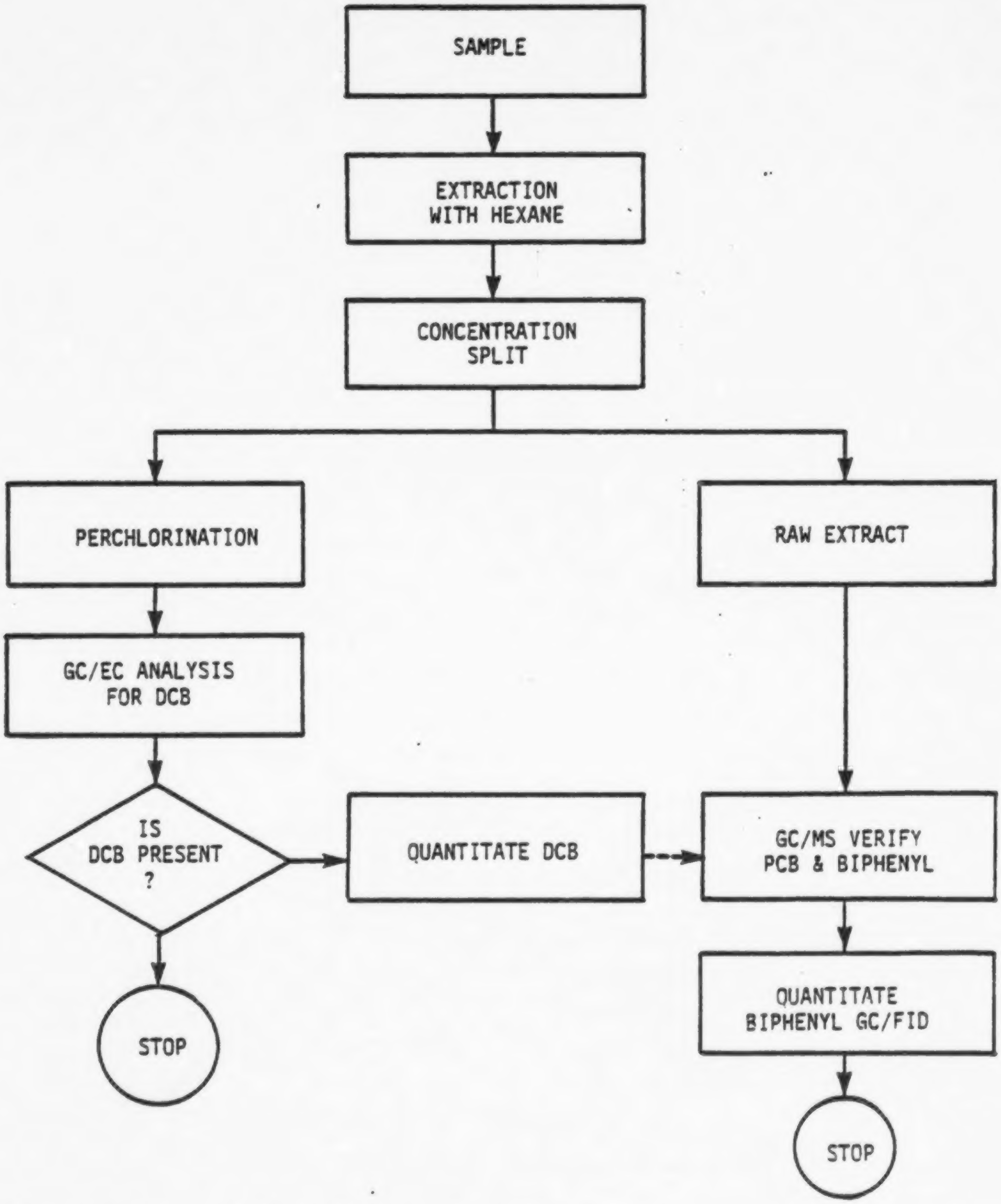

Figure 4-2. General Analytical Scheme for PCB Samples

If DCB is detected then:

- Analyze for and quantitate biphenyl in the raw extract
- Verify the presence of PCB compounds in the raw extract by GC/MS
- Quantitate the DCB level in the perchlorinated fraction

## 4.2 ANALYSIS OF PCBs

This section describes the analytical schemes used to analyze for PCBs in the samples of kiln ash, scrubber liquor, recycled scrubber liquor from the sludge lagoon and stack gases. In all cases the samples collected on test day No. 1 represent a "background" test burn condition during which capacitors containing no PCBs were incinerated. The incineration conditions were essentially the same for the background test on day No. 1 as for days No. 2, No. 3, and No. 4 during which time PCBs were incinerated.

### 4.2.1 Rotary Kiln Ash Analysis

Figure 4-3 illustrates the analytical scheme for the kiln ash. Kiln ash was received in the laboratory as bulk solid material in a 250-ml amber glass jar. By visual inspection, approximately 90 percent of the bulk was small black flakes ranging in size from approximately 2 mm to a fine powder. A few large pieces (up to 75 mm by approximately 20 mm) of metallic-like material were also present.

A representative sample of kiln ash (approximately 50 gm) was transferred directly from the sample container to a preweighed soxhlet thimble. The extraction was carried out in accordance with the soxhlet extraction technique in attachment E of the EPA manual. Following extraction and concentration to 2 ml, the extract was divided into 1-ml portions. One ml of the extract (approximately 50 percent of a 50-gm sample) was submitted to perchlorination in accordance with the EPA report entitled "A Method for Sampling and Analysis of Polychlorinated Biphenyls (PCB's) in Ambient Air." Following the derivatization, the kiln ash samples and method blank were analyzed by gas chromatography/electron capture (GC/EC). The first GC/EC runs showed peaks throughout the chromatogram that were out of the normal working range of the detector. The original perchlorinated fractions were far too concentrated and were subsequently diluted (1000 to 1). This simple dilution enabled the analyst to resolve the DCB peak from other peaks in the chromatogram and to quantitate the DCB peak.

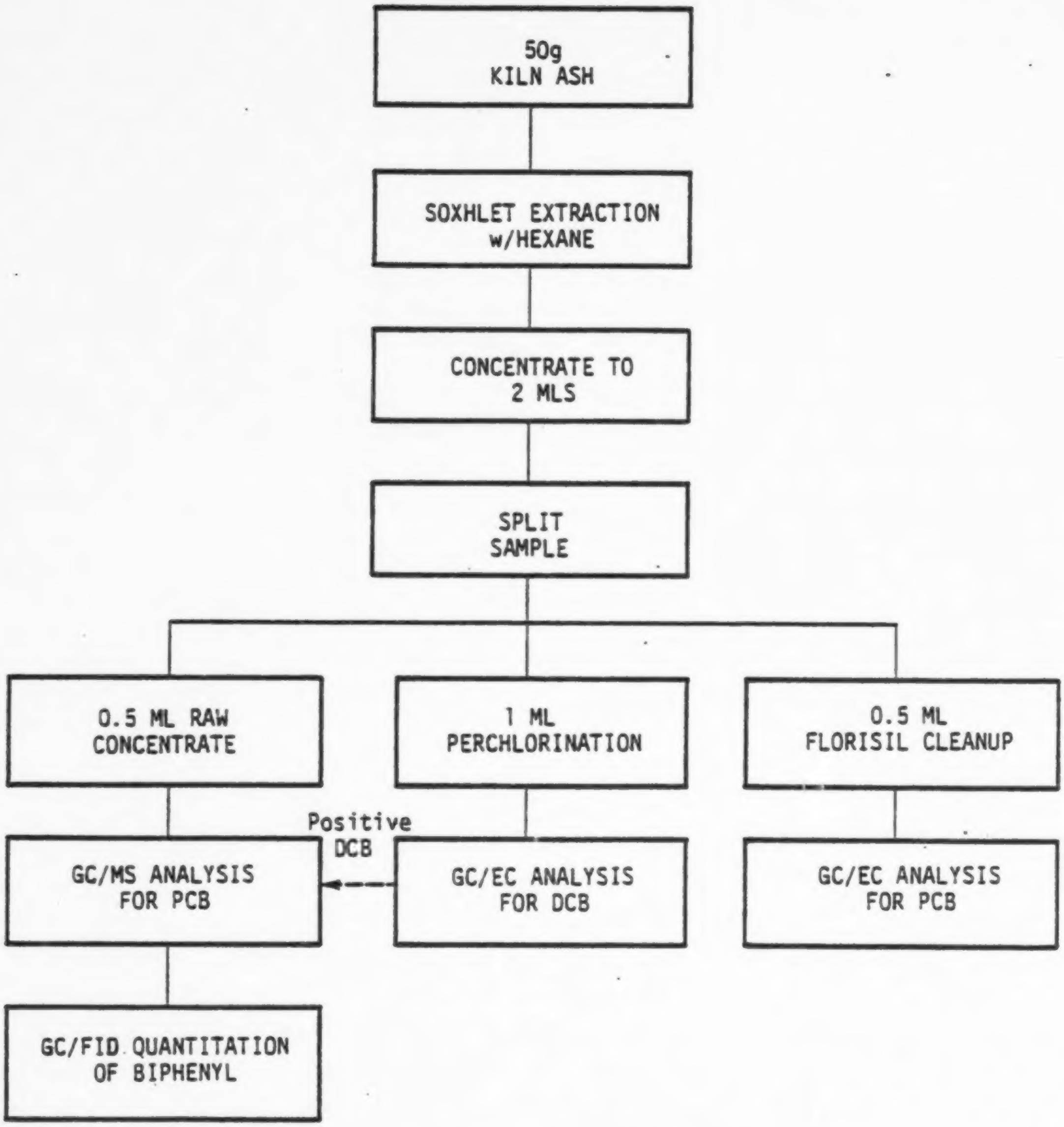

Figure 4-3. Analytical Scheme for Rotary Kiln Ash

Due to the presence of the DCB peak in the kiln ash samples, underivatized portions of the raw extracts were submitted for biphenyl analysis by gas chromatography/ flame ionization detection (GC/FID) and confirmation by GC/MS. Mass spectra are shown in Appendix A. A second portion of the raw extract was submitted for Florisil® cleanup and GC/EC analysis. A PCB pattern was tentatively identified and later confirmed by capillary GC/MS analysis.

Analysis of the 0.5-ml portion of raw extracts (underivatized, no Florisil® cleanup) by capillary GC/MS verified the presence of PCBs ranging from the mono isomer to the penta isomer. Higher chlorinated isomers may have been present, but were not detected. Table 4-1 summarizes the results of all the analyses performed on the rotary kiln ash samples.

### 4.2.2 Scrubber Liquor Effluent and Recycled Scrubber Liquor Analysis

Figure 4-4 illustrates the analytical scheme for the scrubber liquor. Liquor samples were received in the laboratory in 1-gal amber glass jugs. The jugs were thoroughly shaken (due to the fact that approximately half of the volume of the jug was a murky-grey sediment) prior to removing a 1-liter sample for extraction. The extraction procedure was conducted according to Attachment B entitled "A Tentative Method of Testing for Polychlorinated Biphenyls in Water" found in the EPA manual. After completion of the extraction and concentration to 2 milliliters, a visual evaluation was performed to determine the necessity for further chromatographic cleanup procedures. Every sample (8) in the group was judged appropriate for Florisil® cleanup (the sample was colored) and were thus treated in accordance with Section 10.3 of Attachment E of the EPA manual.

In the case of scrubber liquor, the concentrated extract was divided into two equal fractions (1.0 ml each), one of which was submitted to Florisil® chromatography. For the recycled scrubber liquor, the entire concentrated fraction was submitted to Florisil® chromatography. Following the cleanup with Florisil®, the fractions were concentrated on a Kuderna-Danish evaporator and divided into two equal samples. These samples (representing one-half of the recycled scrubber liquor, and one-fourth of the scrubber liquor) were perchlorinated using the same procedure as for the perchlorination of kiln ash samples. In most samples a dilution of 1 to 100 was required to achieve a stable baseline on the recorder of the electron capture gas chromatograph. The samples required dilution prior to analysis to adjust for the unavoidable matrix resulting

## Table 4-1

## ROTARY KILN ASH ANALYSIS AS DECACHLOROBIPHENYL

| | Day #1 | Day #2 | Day #3 | Day #4 |
|---|---|---|---|---|
| Corrected DCB Value (ppm)[a] | 0.52 | 41.94 | 20.15 | 27.21 |
| DCB Value (ppm)[b] | 1.25 | 44.63 | 24.09 | 28.98 |
| Biphenyl Value (ppm)[c] | 0.73 | 2.73 | 4.00 | 1.78 |
| Wet Weight Kiln Ash Extracted (gm) | 50.0744 | 49.7722 | 50.2641 | 50.1284 |
| Percent dry weight[d] | 98.7 | 98.0 | 95.4 | 99.0 |

---

[a] Corrected DCB value using Section 23.7 from "A Method of Sampling and Analysis of PCBs in Ambient Air," EPA Report 600/4-78-048 for presence of biphenyl

[b] Uncorrected DCB value including biphenyl

[c] Corrected to DCB and for biphenyl conversion efficiency of 43.3 percent

[d] $\frac{\text{dry weight}}{\text{wet weight}} \times 100$

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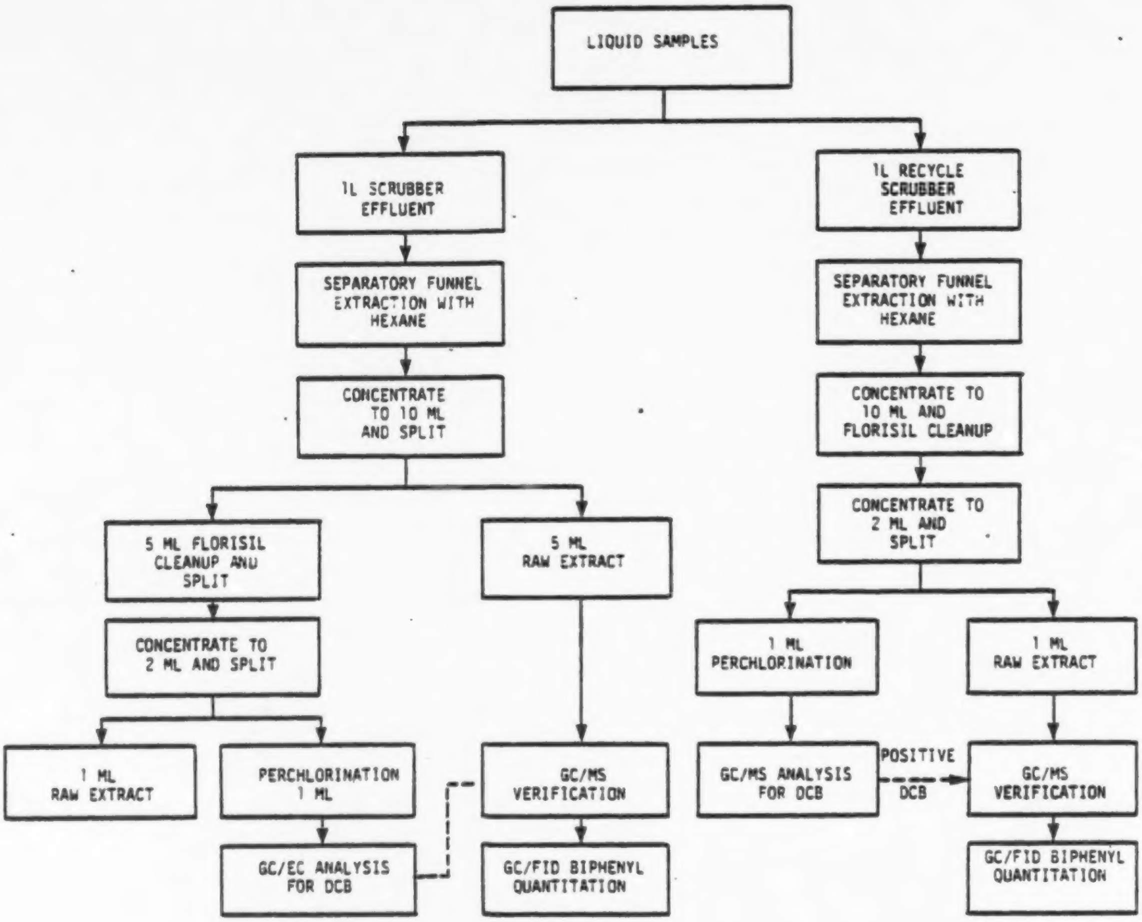
LIQUID SAMPLES
1L SCRUBBER EFFLUENT
1L RECYCLE SCRUBBER EFFLUENT
SEPARATORY FUNNEL EXTRACTION WITH HEXANE
SEPARATORY FUNNEL EXTRACTION WITH HEXANE
CONCENTRATE TO 10 ML AND SPLIT
CONCENTRATE TO 10 ML AND FLORISIL CLEANUP
CONCENTRATE TO 2 ML AND SPLIT
5 ML FLORISIL CLEANUP ANU SPLIT
5 ML RAW EXTRACT
1 ML PERCHLORINATION
1 ML RAW EXTRACT
CONCENTRATE TO 2 ML AND SPLIT
1 ML RAW EXTRACT
PERCHLORINATION 1 ML
GC/MS VERIFICATION
GC/MS ANALYSIS FOR DCB
POSITIVE DCB
GC/MS VERIFICATION
GC/EC ANALYSIS FOR DCB
GC/FID BIPHENYL QUANTITATION
GC/FID BIPHENYL QUANTITATION

Figure 4-4. Analytical Scheme for Scrubber Liquor and Recycled Scrubber Liquor

after extraction and Florisil® cleanup. The levels of DCB found were at the limit of detection for the electron capture detector and in some cases were outside the boundary of responses from the usual 20-pg standard of DCB used as the lower limit.

Unperchlorinated, Florisil®-treated fractions were submitted for GC/FID analysis. Biphenyl was undetectable within the sample matrix. The low levels of DCB detected with the electron capture detector were out of the sensitivity range of the flame ionization detector. A chromatogram of the scrubber liquor is shown in Figure 4-5. The results of the GC/EC analysis for DCB are shown in Table 4-2.

### 4.2.3 Stack Gas Analysis

Figure 4-6 illustrates the analytical scheme for the PCB train used to sample the stack gases. The PCB train samples were received from the field in three separate containers. Florisil® and XAD-2 tubes were sealed outside the ground glass joints with stretched parafilm and were contained within 2-liter wide mouth nalgene bottles. Impinger catches were received in 2-liter amber glass bottles. Probe rinses and impinger washes (1 to 1 hexane/acetone) were collected in 500-ml amber glass bottles. Blank trains were prepared, were recovered each day, and were shipped in identical containers. Blank Florisil® and XAD-2 tubes were shipped in the same wide mouth nalgene bottle as the corresponding test day sample tubes.

Sample extraction procedures were followed as prescribed in Attachment E of the EPA manual. The extraction procedure included soxhlet extraction of combined XAD-2 and Florisil® tubes, separatory funnel extraction of the impinger catches with hexane and a 20-ml portion of acetone used as a rinse, and the hexane portion of a water wash of the hexane-acetone impinger and probe rinse fraction in a 1-liter separatory funnel. These extracts were combined, cleaned and concentrated as outlined in Section 7 of Attachment E. The final volume was adjusted to 40 ml. The 40-ml concentrate was then divided to two portions -- a 35-ml portion that was used for PCB analysis and a 5-ml portion used for total organic chloride (RCℓ) analysis. The 35-ml portion was further concentrated to 5-ml. A 3-ml portion was submitted for perchlorination as outlined in Section 3.1 of Attachment E. The final 2-ml portion was stored at 4°C for further analysis. Analysis of the perchlorinated PCB train samples by GC/EC required dilution by a factor of 100. Results of the DCB analysis is shown in Table 4-3. Representative

2ul 79-3541 Florisil S.B.

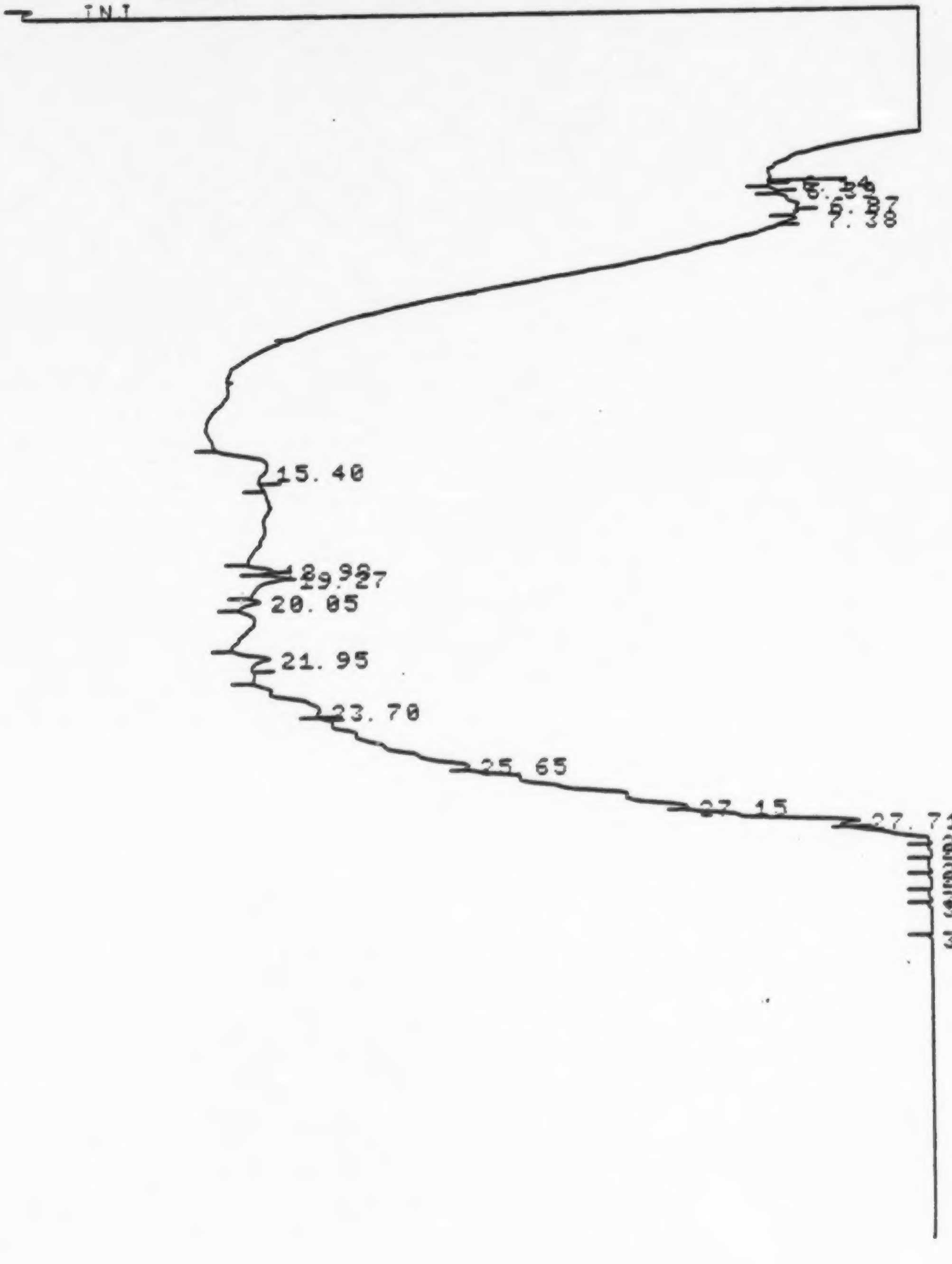

Figure 4-5. Scrubber Liquor Chromatogram

## Table 4-2

## RESULTS OF SCRUBBER LIQUOR AND RECYCLED SCRUBBER LIQUOR ANALYSIS AS DECACHLOROBIPHENYL

| | Scrubber Effluent | | | | Recycle Scrubber Effluent | | | |
|---|---|---|---|---|---|---|---|---|
| | Day #1 | Day #2 | Day #3 | Day #4 | Day #1 | Day #2 | Day #3 | Day #4 |
| GC/MS Confirmation of PCB | U | U | U | U | -- | U | U | U |
| DCB (ppb) | ≤4 | ≤4 | ≤7 | ∿11 | ND | ND | ≤2 | ND |
| Dilution | 1:100 | 1:100 | 1:100 | 1:100 | 1:10 | 1:10 | 1:100 | 1:10 |
| Sample Size | 1 L | 1 L | 1 L | 1 L | 1 L | 1 L | 1 L | 1 L |
| Portion of Sample Perchlorinated | 1/4 | 1/4 | 1/4 | 1/4 | 1/2 | 1/2 | 1/2 | 1/2 |

---

U = unconfirmed

79

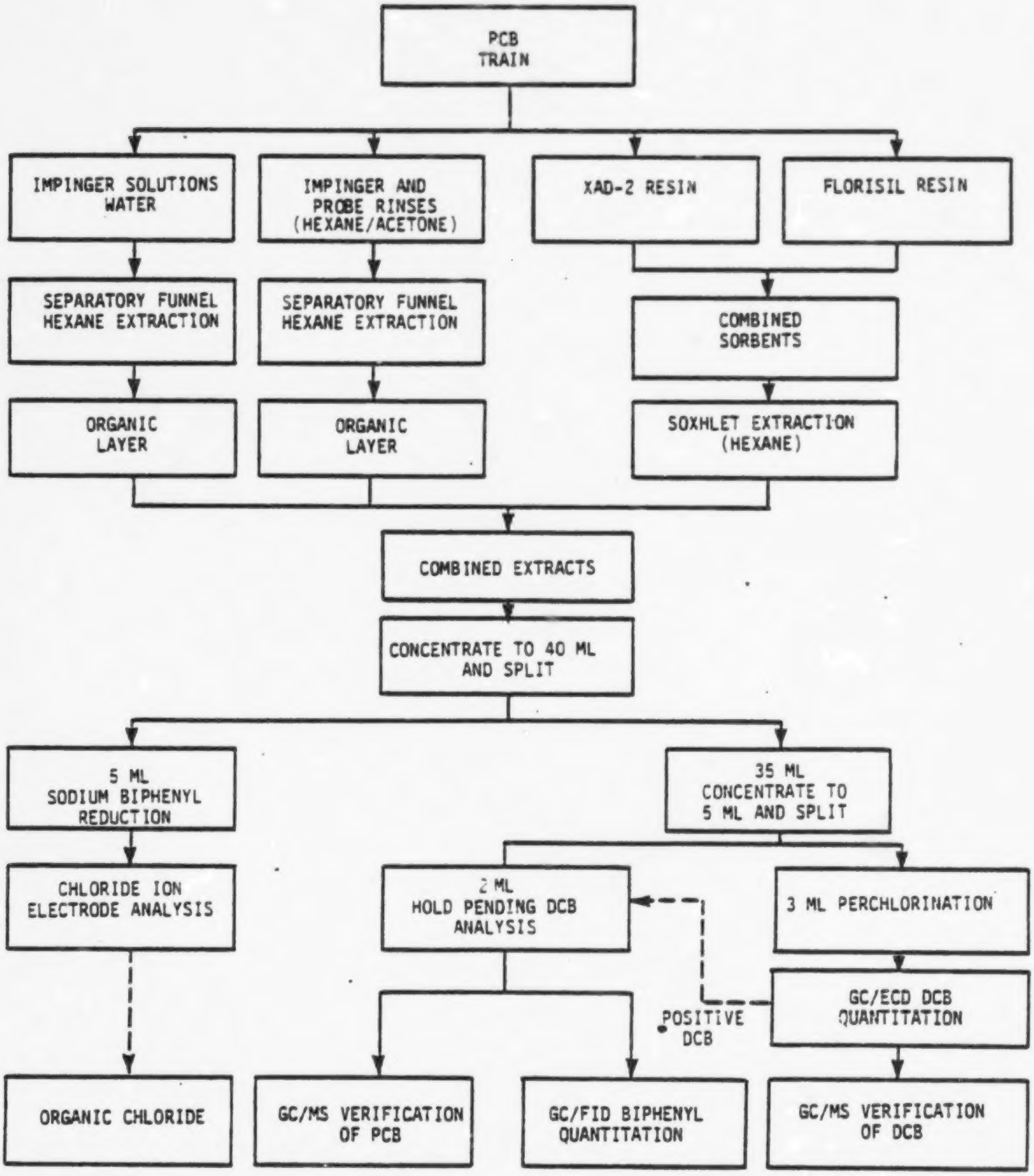
PCB TRAIN
IMPINGER SOLUTIONS WATER
IMPINGER AND PROBE RINSES (HEXANE/ACETONE)
XAD-2 RESIN
FLORISIL RESIN
SEPARATORY FUNNEL HEXANE EXTRACTION
SEPARATORY FUNNEL HEXANE EXTRACTION
COMBINED SORBENTS
ORGANIC LAYER
ORGANIC LAYER
SOXHLET EXTRACTION (HEXANE)
COMBINED EXTRACTS
CONCENTRATE TO 40 ML AND SPLIT
5 ML SODIUM BIPHENYL REDUCTION
35 ML CONCENTRATE TO 5 ML AND SPLIT
CHLORIDE ION ELECTRODE ANALYSIS
2 ML HOLD PENDING DCB ANALYSIS
3 ML PERCHLORINATION
GC/ECD DCB QUANTITATION
POSITIVE DCB
ORGANIC CHLORIDE
GC/MS VERIFICATION OF PCB
GC/FID BIPHENYL QUANTITATION
GC/MS VERIFICATION OF DCB

Figure 4-6. Analytical Scheme for PCB Stack Gas Sampling Train

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## Table 4-3

## RESULTS OF STACK GAS ANALYSIS

| | Day #1<br>79-3472<br>(μg/train) | Day #2<br>79-3474<br>(μg/train) | Day #3<br>79-3476<br>(μg/train) | Day #4<br>79-3478<br>(μg/train) |
|---|---|---|---|---|
| Capillary GC/MS for PCBs | ND | ND | ND | ND |
| DCB[a]-- GC/EC | 35 | 120 | 63 | 167 |
| DCB — GC/MS | Confirmed DCB | Confirmed DCB | Confirmed DCB | Confirmed DCB |
| Biphenyl by GC/FIC[b] | * | * | * | * |
| Biphenyl by GC/MS | ND | 3 | 1 | ND |
| Corrected DCB levels[c] | 35 | 116 | 61 | 167 |

---

[a] The equation used to obtain the above GC/EC results is

$$\frac{\text{Area Counts x RF}}{\mu\ell : \text{injected}} \times \text{Amount Sample Volume} \times \frac{8}{7} \times \frac{5}{3}$$

[b] Detected at or below the level of quantitation (detection limits: 50 pg GC/EC, 100 pg GC/MS)

[c] Biphenyl levels subtracted when detected and quantified by GC/MS

81

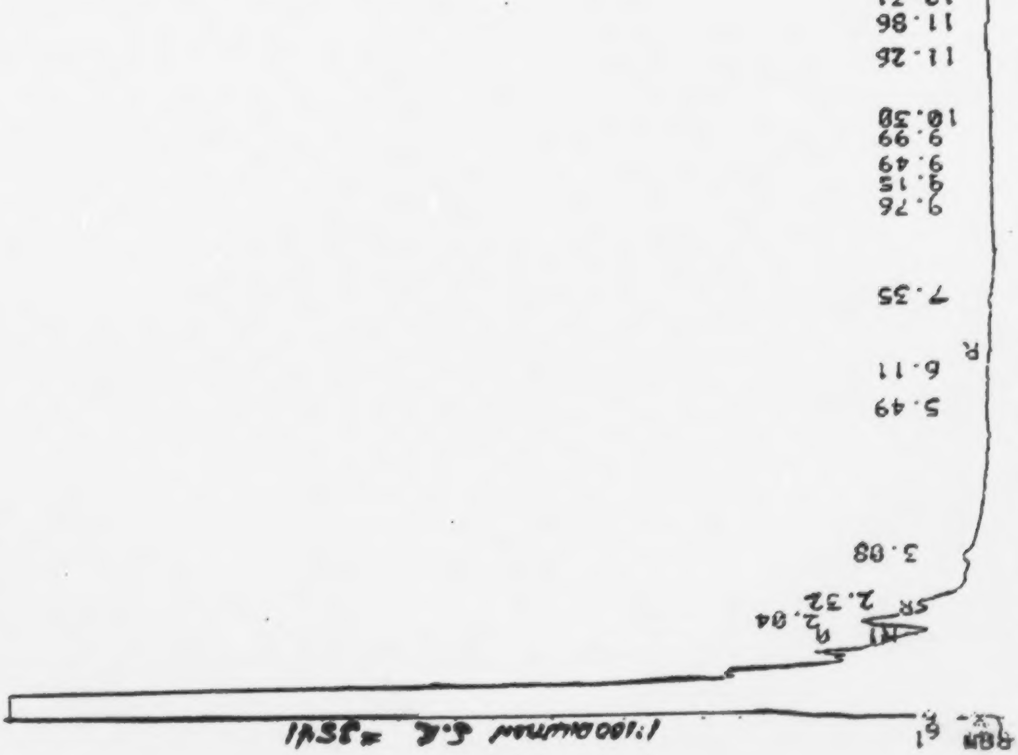

Figure 4-7. Chromatogram of Perchlorinated PCB Train Sample

chromatograms are shown in Figure 4-7. The DCB levels observed in these analyses, after subtraction of mean PCB blank train values of DCB, indicated a need for biphenyl correction. GC/FID analysis for biphenyl were performed on an underivatized portion of the PCB train samples. Chromatograms obtained for these analyses were inconclusive and suggested that further analysis was in order. GC/MS analysis of the perchlorinated fractions confirmed the presence of DCB (see Figure 4-7) in approximately the concentration range as measured with GC/EC analysis. Capillary GC/MS chromatograms of underivatized samples were evaluated for the presence of biphenyl and for PCBs. This evaluation suggested the biphenyl was present at very low levels, but no PCBs could be detected in the underivatized samples. A GC/MS procedure was used for quantitation of biphenyl. The results of this analysis is shown in Table 4-4. Mass spectra are shown in Appendix A.

## 4.3 ANALYSIS FOR TOTAL ORGANIC CHLORINE

A portion of the PCB train concentrate (5-ml of 40-ml total) was submitted to total organic chlorine analysis. Ligget's (7) sodium biphenyl reduction method was used. The sample was solvent exchanged from hexane to halide free toluene, then reduced with sodium biphenyl. After cleanup and decomposition, the sample was subjected to chloride analysis with a chloride specific electrode. A method blank and a standard Aroclor 1260 sample were run for QA/QC.

The detection limit for the method was determined to be 0.5 mg total organic chloride in the train. There was no organic chloride detected in samples from days 2 through 4. A slight positive was found for day 1 (approximately 0.9 mg). This is believed to be a contamination problem. The chloride spike and recovery sample gave 100 percent recovery. The standard Arclor sample gave 96 percent recovery based on a literature value of 60 percent wt/wt chlorine in Aroclor 1260.

It is concluded that no organic chlorine was collected in the PCB train at the detection limits of the methodology.

## 4.4 ANALYSIS OF PARTICULATE MATTER

Analysis of the particulate matter collected in the stack gas sampling train was in accordance with EPA Method 5. All filters and acetone residues were desiccated and weighed to the nearest 0.05 mg on a Mettler Model H51AR analytical balance. Blanks were treated in an identical manner. Table 4-5 summarizes the results of these analyses.

## Table 4-4

## BIPHENYL ANALYSIS OF PCB STACK GAS SAMPLING TRAIN SAMPLES BY GC/MS

| Acurex I.D. | Identification | Area Counts | μg Biphenyl/train | μg/Train Biphenyl[a] Corrected to DCB |
|---|---|---|---|---|
| 79-3472 | PCB Train Day #1 | ND | ND | ND |
| 79-3474 | PCB Train Day #2 | 10315 | 2.68 | 3.87 |
| 79-3476 | PCB Train Day #3 | 4440 | 1.15 | 1.166 |
| 79-3478 | PCB Train Day #4 | ND | ND | ND |
| 79-3477[b] | PCB Train Blank Day #3 | 526 | 0.14 | 0.20 |
| 79-3479 | PCB Train Blank Day #4 | 470 | 0.12 | 0.17 |

---

Note: Biphenyl conversion efficiency to DCB is 42 to 48 percent

[a] Amount Biphenyl x $\frac{499}{154}$ x 0.45

[b] Two of the four blank trains were selected at random for analysis.

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## Table 4-5

## ANALYSIS OF PARTICULATE MATTER, HCℓ, $NO_x$ and RCℓ[a]

| | Day #1 | Day #2 | Day #3 | Day #4 |
|---|---|---|---|---|
| Total particulate (mg) | 420.21 | 1351.31 | 820.63 | 1198.05 |
| Total chloride (mg) | 97.0 | 170.0 | 450.0 | 320.0 |
| Total $NO_x$ (μg $NO_2$)[b] | 1.5<br>52.0<br>71.0<br>27.0 | 5.2<br>78.0<br>6.3<br>72.0 | 40.0<br>60.0<br>9.4<br>37.0 | 20.0<br>27.0<br>91.0<br>18.0 |
| Total RCℓ (mg organic chlorine)[c] | ND | ND | ND | ND |

---

[a] Results are corrected for blanks
[b] Micrograms of nitrogen dioxide
[c] Lower detectable limit is 0.5 mg

## 4.5 ANALYSIS OF HYDROCHLORIC ACID

Analysis of the HCℓ collected in the impingers of the particulate sampling train was done according to the argentometric method described in the 14th Edition of "Standard Methods for Examination of Water and Wastewater" published by the American Public Health Association in 1975. The total volume of impinger liquid was measured and a representative aliquot of the liquid was titrated with silver nitrate to determine the chloride content of the liquid. A blank was also run on the distilled water used in the impinger trains. Table 4-5 summarizes the results.

## 4.6 ANALYSIS OF $NO_x$

Analysis of the $NO_x$ samples collected during the trial burn were done in accordance with EPA Method 7 -- the phenoldisulfonic acid procedure. A blank of the absorbing solution was also analyzed. The results are summarized in Table 4-5.

## 4.7 QUALITY CONTROL AND QUALITY ASSURANCE

Quality control/quality assurance measures necessary to insure the integrity of the ppb level analysis of PCBs require strict attention to the linearity of the analysis (i.e., calibration curves) and to the quality of solvents and reagents used in the sample preparation stage.

In addition to Acurex laboratory quality control measures, PCB audit samples were supplied by William D. Langley, Ph.D. of the Environmental Protection Agency Region 6, Houston, Texas (see Appendix B). Acurex performed and passed this audit check which consisted of determining Aroclor mixtures (qualitative) and establishing the PCB concentrations (quantitative) in each of these liquid samples prior to conducting any analysis of the field samples.

Solvent purities, based on analysis of a representative sample from identifiable lot numbers were quality checked by GC/MS. Samples, representing 250 ml of solvent concentrated to 1 ml on a Kuderna-Danish evaporator, were submitted for analysis. Electron impact spectra were collected during the entire programmed chromatographic run. Diagnostic PCB ions were plotted as a function of time to determine if any PCB compounds were present. This procedure allowed evaluation of solvent purity to the low ppb level. All solvents used in the analysis were judged "PCB free."

Method blanks were used to further ensure solvent and reagent purity. These samples were prepared in an identical manner to the perchlorinated field samples and showed no contribution at the retention time of DCB. Method blank chromatograms are shown in Figure 4-8.

Perchlorination efficiency was monitored to insure the ability to quantitatively derivatize known standards. Results of these perchlorination experiments established the average efficiency of the reaction as 100 percent. The Aroclor preparation used in these experiments was Aroclor 1260 prepared in 1 mg/ml stock solution as supplied by the EPA. Literature values indicate Aroclor 1260 is composed of approximately 60 percent $C\ell$, with an average of 6.3 $C\ell$/molecule and an average molecular weight of 372. Therefore 74.5 percent of the weight of DCB detected represents the weight of Arochlor 1260 derivatized (342/499). Using the formula:

$$\frac{\left(\begin{array}{l}\text{Area counts of}\\ \text{derivitized}\\ \text{Aroclor 1260}\end{array}\right)\left(\frac{1}{0.137\ \frac{ac}{pg}}\ \begin{array}{c}\text{DCB}\\ \text{Std}\end{array}\right) \times (0.745)}{\left(\begin{array}{l}\text{Wt inject}\\ \text{Arochlor 1260}\end{array}\ (pg)\right)} \times (100) = \begin{array}{l}\text{Perchlorination}\\ \text{efficiency}\end{array}$$

Perchlorination efficiency may vary for different Aroclor mixtures. Two levels of Aroclor 1260 were perchlorinated. Samples were derivatized using the same procedure as outlined in Section 4.2.1. The area counts observed from the GC/EC analysis were 25.619 and 56.781 respectively for 100 pg and 250 pg of Aroclor 1260. As a standard for these experiments, a 50-pg injection of DCB was used which resulted in 0.137 ac/pg of DCB. A portion of Aroclor 1260 was subjected to total organic chlorine analysis. The actual weight percent chlorine for this standard material was found to be 57.8 percent.

Standard calibration curves were established by injecting dilutions of authentic standards (8) for decachlorobiphenyl by GC/EC and for biphenyl by GC/FID. Calibration curves (see Figures 4-9 and 4-10) for these compounds show a linear response that was plotted by the use of the linear regression equation.

## 4.8 SUMMARY AND CONCLUSION

As can readily be seen from the data in Tables 4-1 through 4-3, the kiln ash contained by far the highest levels of DCB observed. The difference between the background burn (day 1) and the PCB burn (days 2 through 4) is quite evident. The

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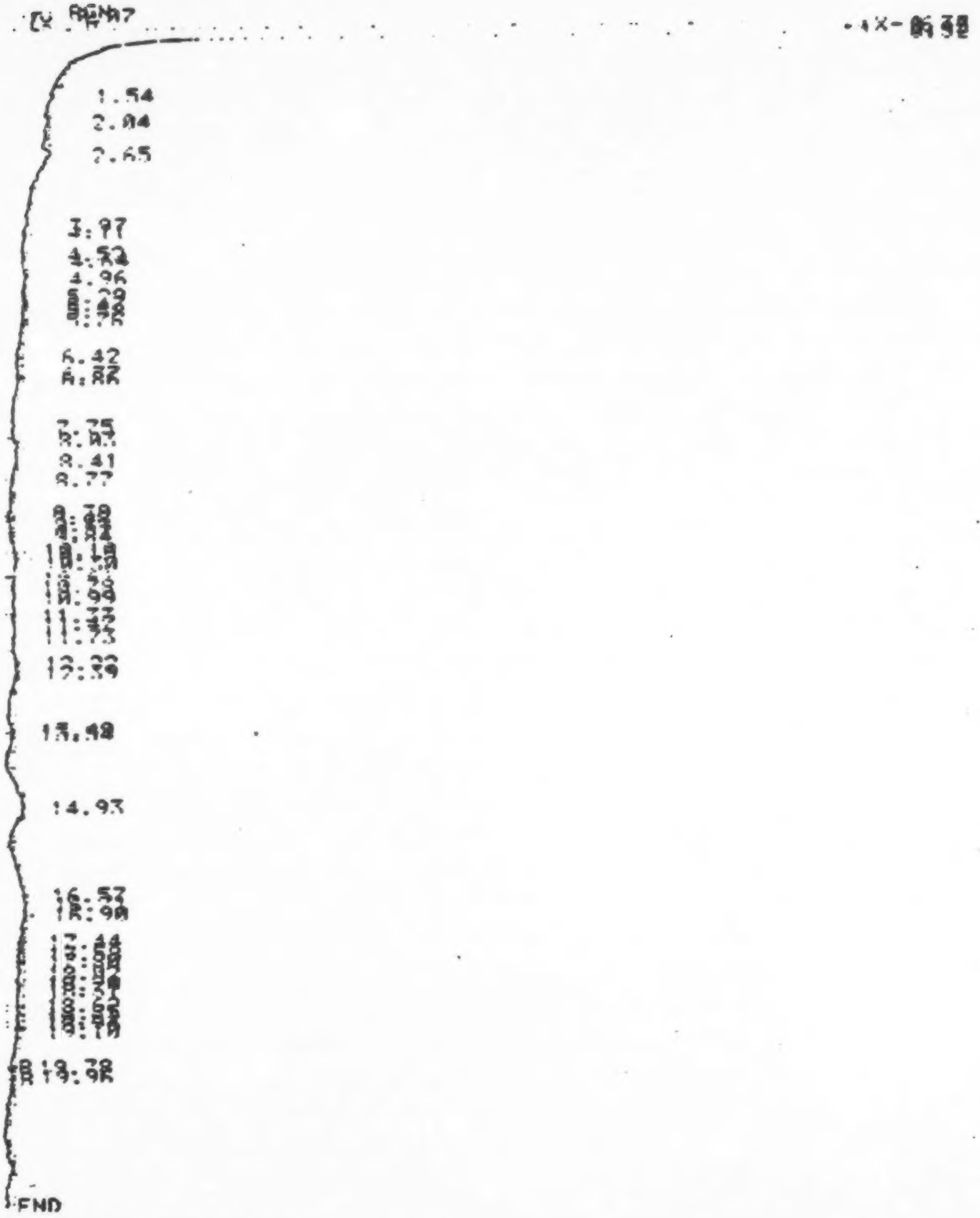


Figure 4-8. Method Blank Chromatogram

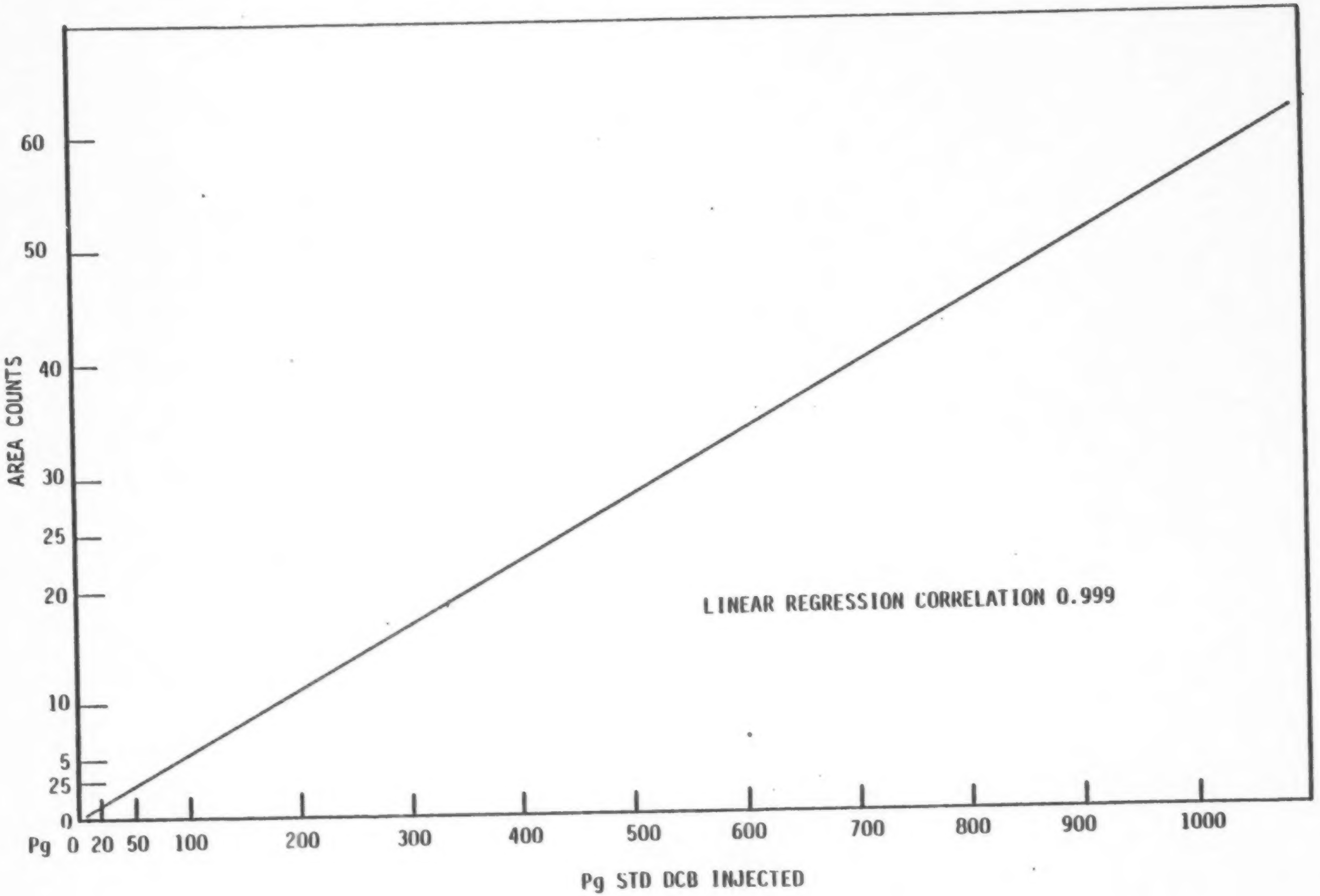


Figure 4-9. Decachlorobiphenyl Calibration Curve (GC/EC)

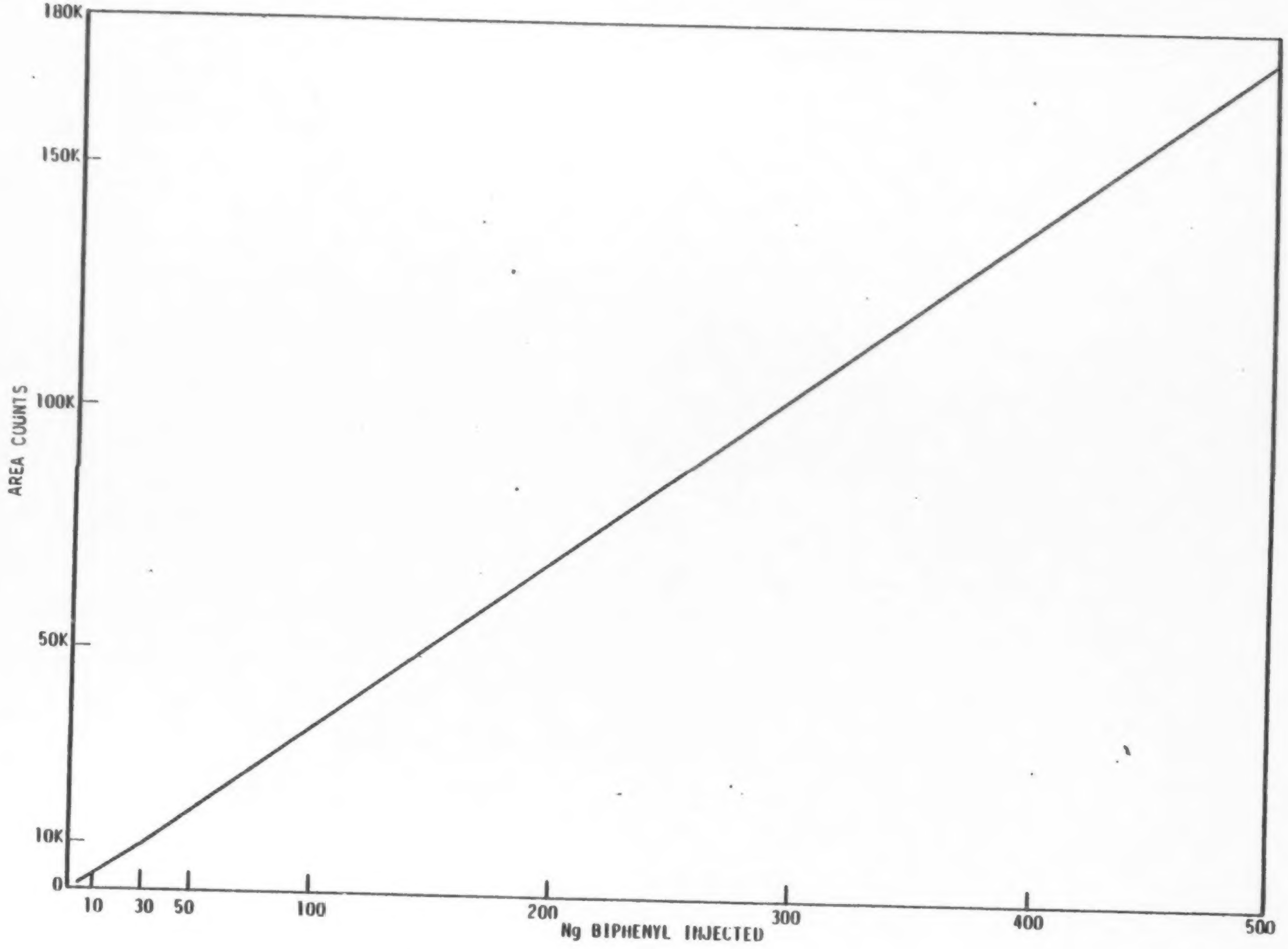


Figure 4-10. Biphenyl Standard Curve (GC/FID)

presence of PCBs in unperchlorinated fractions of the kiln ash extract was confirmed by GC/MS identification. In addition, numerous chlorinated and unchlorinated compounds were identified and shown to be predominately polynuclear aromatics.

Results of analyses of the two liquid streams (the scrubber effluent and the recycle scrubber effluent) are also clear and specific for the presence of DCB. However, the levels were barely above the quantitation limits by GC/EC and the presence of PCBs was not verifiable by GC/MS.

The stack gas samples also showed the presence of DCB and at sufficient levels for good quantitation. The presence of DCB in the perchlorinated fractions was confirmed by GC/MS. However, PCBs could not be detected in the unperchlorinated portions of the sample. These results support the work of Haile (as reported by Levins) which concludes that the perchlorination procedure can result in false positive values for PCBs when applied to combustion source emissions. Furthermore, this validates the necessity of GC/MS verification for PCBs when the DCB procedure is used for the quantitation of PCBs in combustion sources.

In conclusion, PCBs are present in the kiln ash at the parts per million level; PCBs are not present at the detectable limits of the methodology in the scrubber effluent streams, and are not present in the stack gas emissions above 50 $\mu g/m^3$ (less than 50 ppb weight PCBs in stack gas per unit weight PCB burned).

Based upon the available literature and the experience that Acurex has gained from participation in this test incineration, the following recommendations are made:

- Utilize the DCB-perchlorination methodology with strict reservations

  Divide all samples to be perchlorinated into two or more fractions. If any of the derivatized samples show positive results, confirm with a different method (i.e., GC/MS)

- Adopt a method similar to that outlined in the article by Webb & McCall and presented in "Measurement of PCB Emissions from Combustion Sources," EPA-600/7-79-047, February 1979 for the definitive evaluation of suspected PCB-containing samples from combustion sources

# SECTION 5

# RESULTS OF PCB TRIAL BURN

This section of the report summarizes the test results from the PCB trial burn conducted at the Energy Systems Company in El Dorado, Arkansas.

## 5.1 RETENTION TIME

The EPA regulations specify that retention time in the incinerator must be 2 seconds at 2192°F with 3 percent excess oxygen in the stack gas or 1.3 seconds at 2912°F with 2 percent excess oxygen in the stack gas.

The rotary kiln had a retention time of ~3.7 seconds at 1400°F (average) during the trial burn. The afterburner, which consisted of a primary and secondary combustion chamber, and a passageway had retention times of ~2.19 seconds at 2290°F (average primary), ~2.11 seconds at 1915°F (average secondary), and ~0.23 second at 2280°F (passageway) during the trial burn. The average excess oxygen level (measured at the scrubber outlet) was 13.35 percent. Hence, the ENSCO facility exceeded the minimum EPA requirements for retention time, temperature and excess oxygen required for efficient destruction of PCBs.

## 5.2 COMBUSTION EFFICIENCY

EPA requires that the combustion efficiency of the incinerator be at least 99.9 percent. Based on the results of the gas analysis at the scrubber outlet using the continuous stack gas monitors (for CO and $O_2$) and the Orsat (for $CO_2$), the concentration of CO averaged <10 ppm and the average concentration of $CO_2$ was 5.45 percent. Hence, the combustion efficiency of the incinerator (greater than 99.98 percent) exceeded the minimum criteria of 99.9 percent.

## 5.3 FEEDRATE OF PCBs

The feedrate of liquid PCBs and the feedrate of shredded electronic capacitors fed to the incinerator were measured and recorded during the trial burn. The average feedrate for the 3 PCB test burns was 393 lb/hr of liquid PCBs and 243 lb/hr of PCBs in the shredded capacitors for a total average PCB input of 636 lb/hr

## 5.4 TEMPERATURES OF INCINERATION

The temperatures of the incineration process were continuously measured during the trial burn using thermocouples in the walls of the chambers. As indicated previously, the average temperatures in the rotary kiln, primary combustion chamber and secondary combustion chamber were 1400°F, 2290°F and 1915°F respectively.

## 5.5 AUTOMATIC SHUTOFF FOR PCBs

The EPA regulations specify that the flow of PCBs to the incinerator must be automatically shutoff when the combustion temperatures drop below the specified limits. The ENSCO incinerator is equipped with automatic shutoff capability. The automatic shutoff device can be triggered by low-temperature (<2050°F), high CO (>50 ppm) and low excess oxygen (<4.5 percent) and, in fact, was triggered on several occasions for short periods of time due to fluctuating CO levels. The fluctuating CO levels resulted from variations in the liquid organic waste feed rate which caused momentary fuel rich conditions occasionally, resulting in CO levels >50 ppm.

## 5.6 MONITORING OF STACK EMISSIONS

The stack emissions were monitored during the PCB trial burn and the results are presented in Table 5-1.

## 5.7 MONITORING OF COMBUSTION PRODUCTS

EPA requires continuous monitoring for $O_2$ and CO and periodic monitoring for $CO_2$ during the incineration of PCBs. Table 5-2 illustrates the results for the trial burn. These results were obtained from measurements made at the outlet of the venturi scrubber.

## 5.8 WATER SCRUBBERS

EPA requires that water scrubbers be used to control emissions of HCℓ during PCB incineration. Since the scrubber liquor drains to the sludge lagoon and is recycled back to the scrubber, no effluent leaves the ENSCO property. These two streams were monitored during the trial burn for PCBs and PCBs were not detected in either stream.

Table 5-1

STACK EMISSIONS DURING PCB TRIAL BURN

| Parameter | Day #1[a] 10/15/79 | Day #2 10/16/79 | Day #3 10/17/79 | Day #4 10/18/79 |
|---|---|---|---|---|
| Oxygen (%) | 16.6 | 17.2 | 16.6 | 15.6 |
| Carbon Monoxide (%) | ND | ND | ND | ND |
| Carbon Dioxide (%) | 1.8 | 2.8 | 2.8 | 3.0 |
| Oxides of Nitrogen (lb/hr) | 3.5 | 3.6 | 3.3 | 3.4 |
| Hydrochloric Acid (lb/hr) | 12.8 | 22.3 | 58.3 | 41.2 |
| Total Chlorinated Organics (lb/hr) | ND[b] | ND | ND | ND |
| PCBs (mg/kg feed) | ND | ND | ND | ND |
| Total Particulate Matter (lb/hr) | 55.8 | 176.5 | 107.3 | 156.7 |

---

[a] Background test burn; no PCBs incinerated

[b] Not detected

Table 5-2

MONITORING RESULTS OF COMBUSTION PRODUCTS

| Parameter | Day #1 10/15/79 | Day #2 10/16/79 | Day #3 10/17/79 | Day #4 10/18/79 |
|---|---|---|---|---|
| Oxygen (%) | 14.2 | 13.2 | 13.8 | 13.1 |
| Carbon Monoxide (ppm) | 10 | 6 | 4 | 4 |
| Carbon Dioxide (%) | 4.5 | 5.8 | 4.9 | 5.6 |
| Combustion Efficiency |  | 99.989 | 99.991 | 99.992 |

## 5.9 MASS AIR EMISSIONS

When burning nonliquid PCBs (e.g., solid electronic capacitors) EPA requires that the mass air emissions from the incinerator shall be no greater than 0.001 gm PCB per kg of PCB fed to the incinerator. Since PCBs were not detected at considerably below this specified concentration, this standard was not exceeded during this PCB trial burn.

## 5.10 KILN ASH

PCBs were detected in the rotary kiln ash at levels <50 ppm which is lowest limit of PCBs currently regulated by EPA. This ash can be landfilled at an approved chemical landfill.

In summary, the ENSCO incineration facility has satisfied the requirements listed in Annex I of the EPA rules and regulations governing the disposal of PCBs by incineration as published in the Federal Register, Volume 44, No. 106 on Thursday, May 31, 1979 and has successfully completed the PCB trial burn.

95

## REFERENCES

1. Hutzinger, O., et al. The Chemistry of PCB's CLeveland: CRC Press, 1974.

2. Armour, J. "Quantitative Perchlorination of Polychlorinated Biphenyls as a Method for Confirmatory Residue Measurement and Identification." JAOAC, 56:986, 1973.

3. Haile, C. PCB Interlaboratory Verification Analysis. Midwest Research Institute, Final Report for EPA Contract 68-02-1399, December 27, 1976.

4. Webb, R., and A. McCall. "Quantitative Standards for Electron Capture Gas Chromatography." J. Chroma. Sci., 11:366, 1973.

5. Eichelberger, J., et al. "Analysis of the Polychlorinated Biphenyls Problem." Anal. Chem., 46:227, 1974.

6. Environmental Assessment of PCBs in the Atmosphere. Environmental Protection Agency. EPA-450/3-77-045, November 1977.

7. Ligget, L. M. "Determination of Organic Halogen with Sodium Biphenyl Reagent." JAM Chem, 24, April 1954.

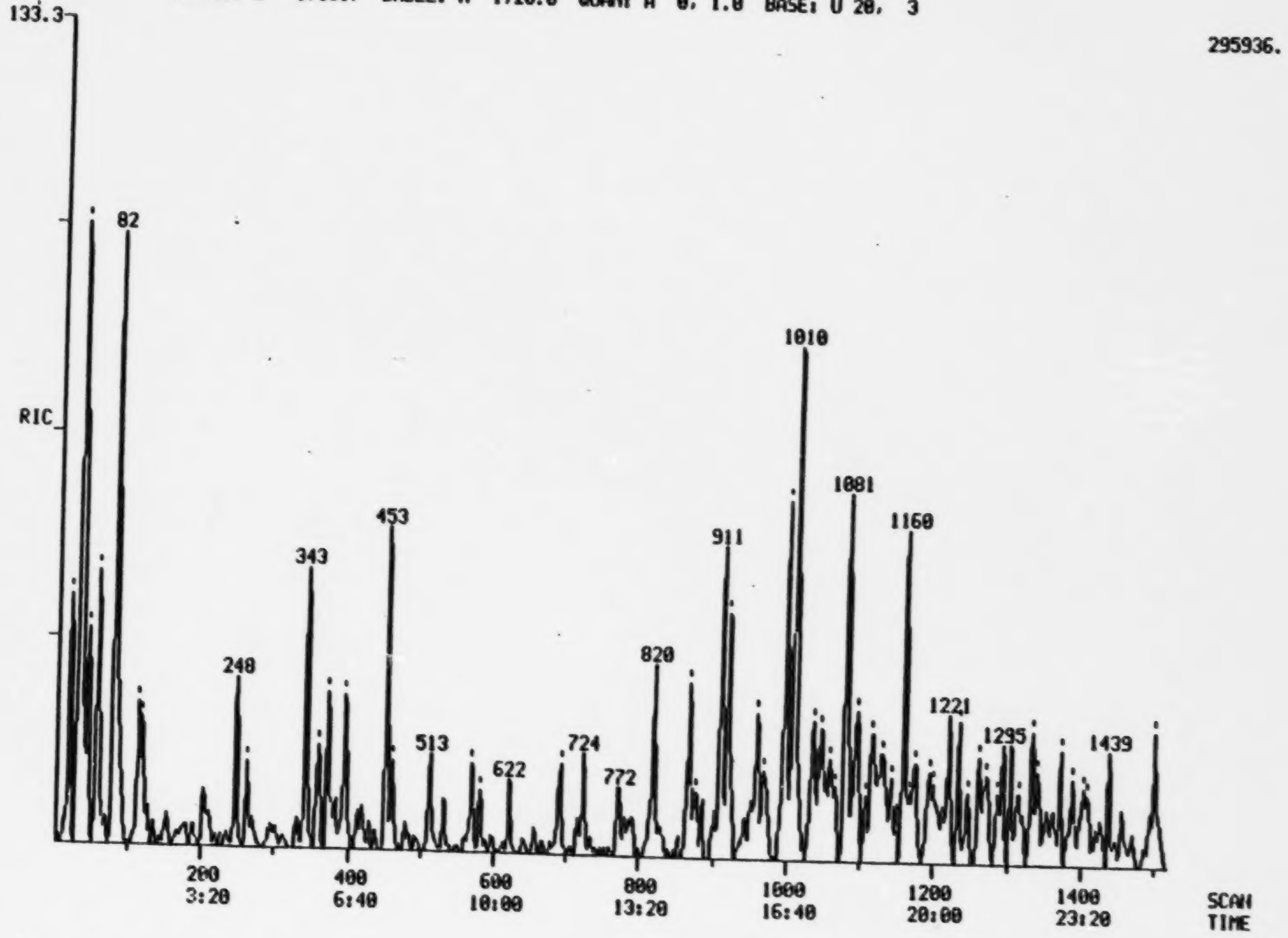
8. Baker, J. T. and Supelco

# APPENDIX A

RIC
01/02/80 10:50:00
SAMPLE: 79-3472 PCB TRAIN DAY#1 4UL
RANGE: G 1,1517 LABEL: N 1,20.0 QUAN: A 0, 1.0 BASE: U 20, 3

DATA: PCB3472 #1
CALI: C1280 #3

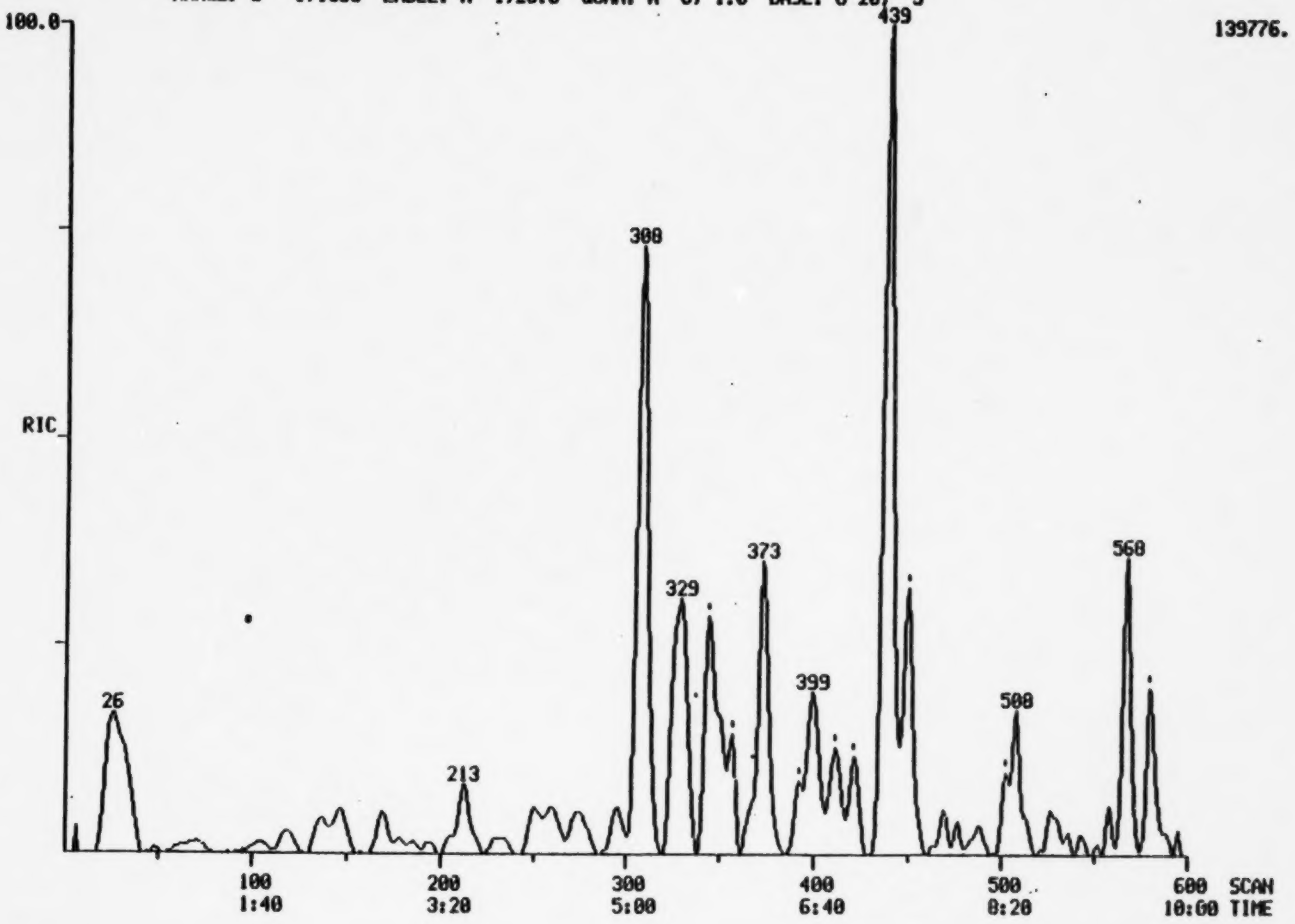
SCANS 1 TO 1517



RIC
01/02/80 10:10:00
SAMPLE: 79-3474 PCB TRAIN DAY2 4UL1NJ
RANGE: G 1,1695 LABEL: N 1,20.0 QUAN: A 0, 1.0 BASE: U 20, 3

DATA: PCB3474 #1
CALI: C1200 #3

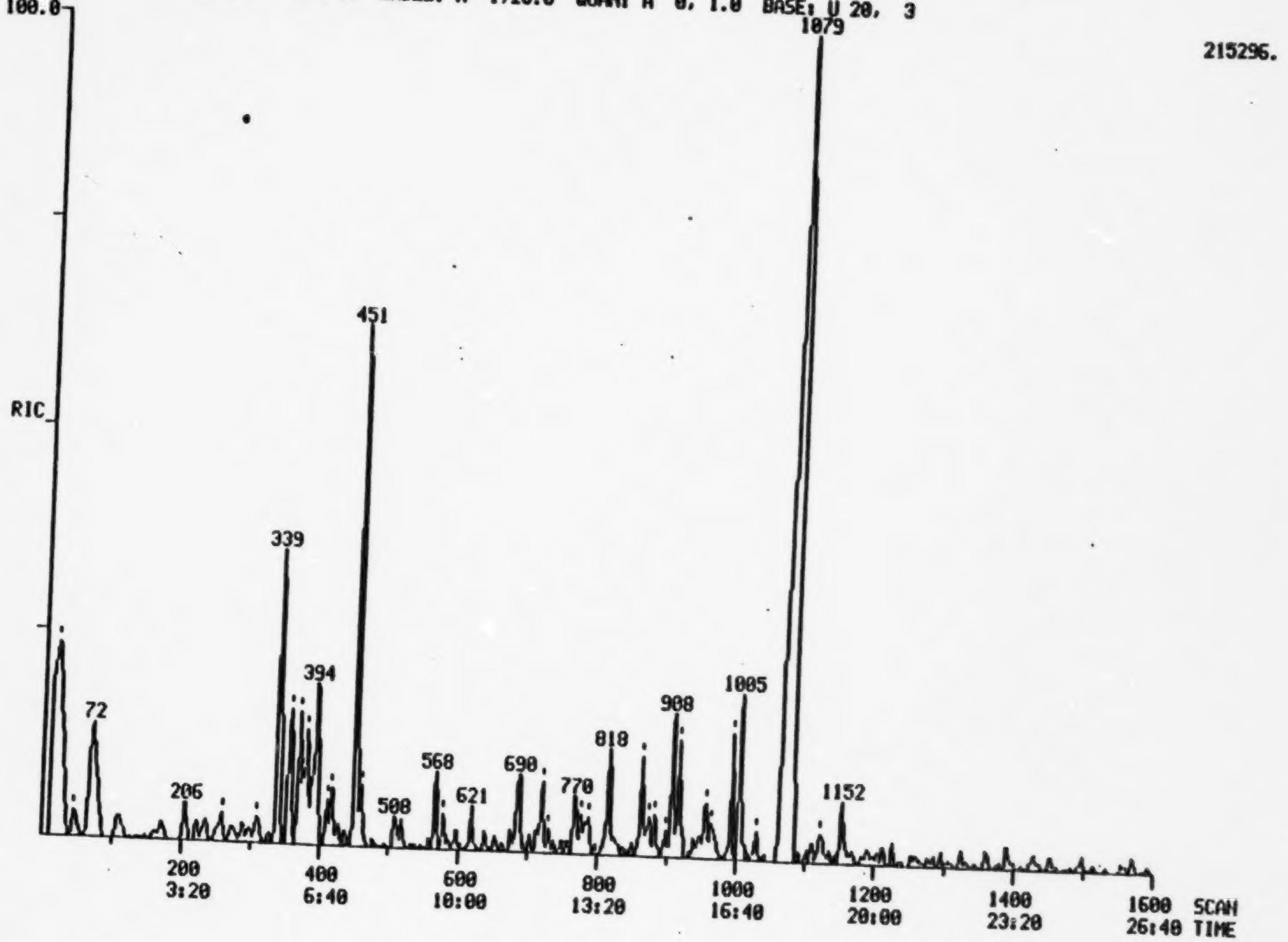
SCANS 1 TO 600



RIC
01/02/80 9:24:00
SAMPLE: 79-3476 PCB TRAIN DAY#3 4UL
RANGE: G 1,2000 LABEL: N 1,20.0 QUAN: A 0, 1.0 BASE: U 20, 3

DATA: PCB3476 #1
CALI: C1200 #3

SCANS 1 TO 1600

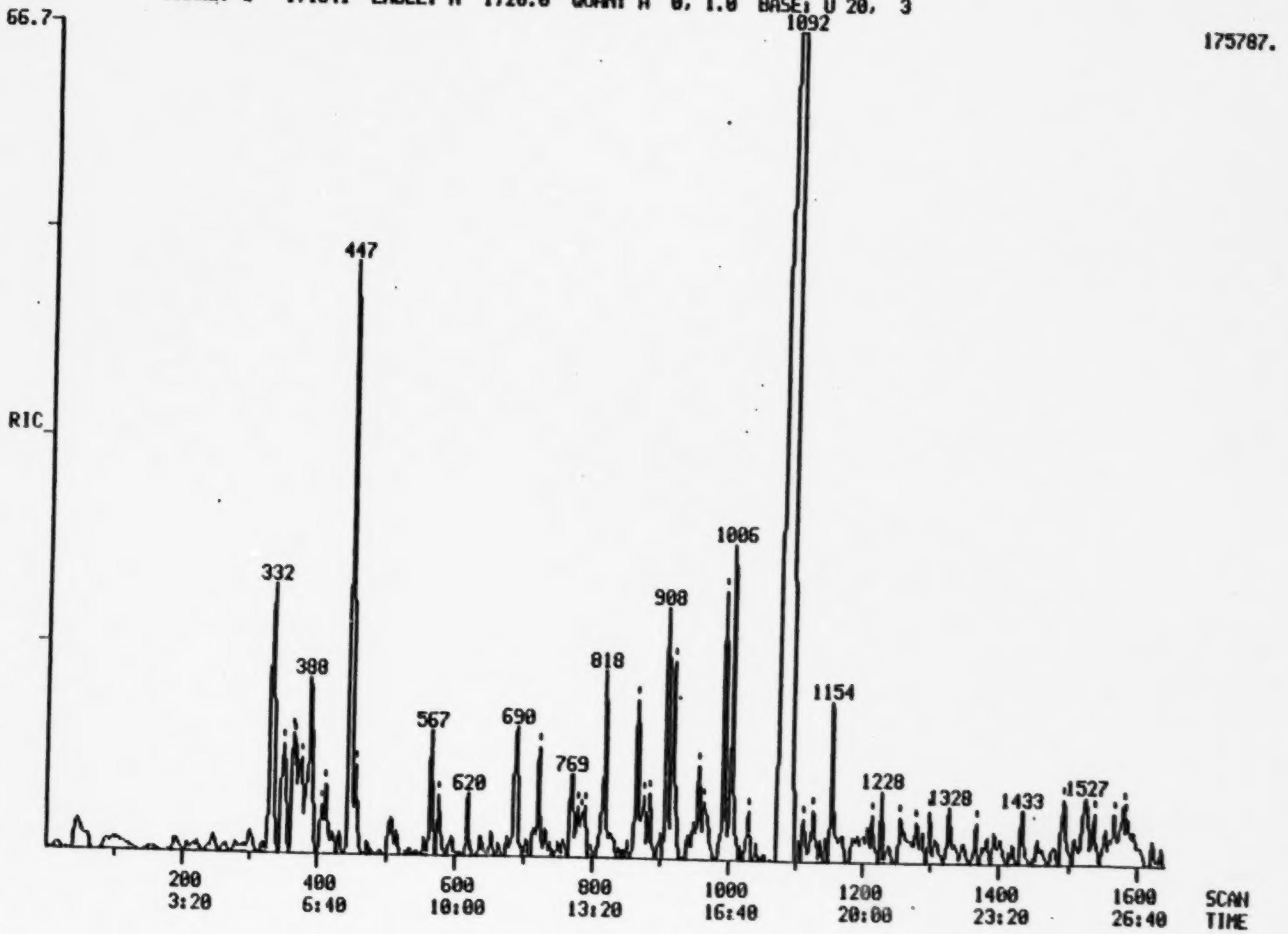


100

RIC
01/02/80 8:44:00
SAMPLE: 79-3478 PCB TRAIN DAY#4 2UL INJECTED
RANGE: G 1,1641 LABEL: N 1,20.0 QUAN: A 0, 1.0 BASE: U 20, 3

DATA: PCB3478 #1
CALI: C1200 #3

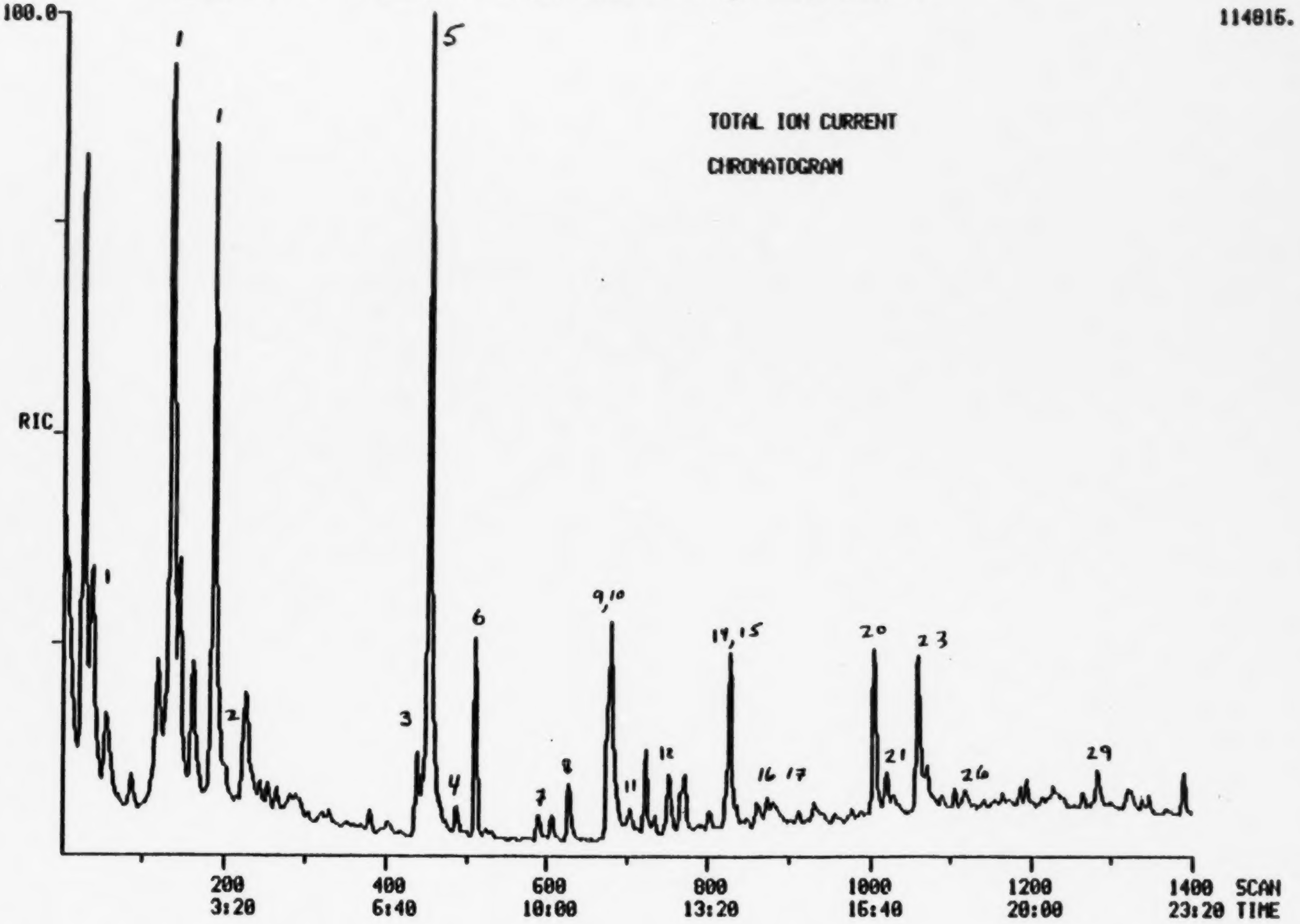
SCANS 1 TO 1641



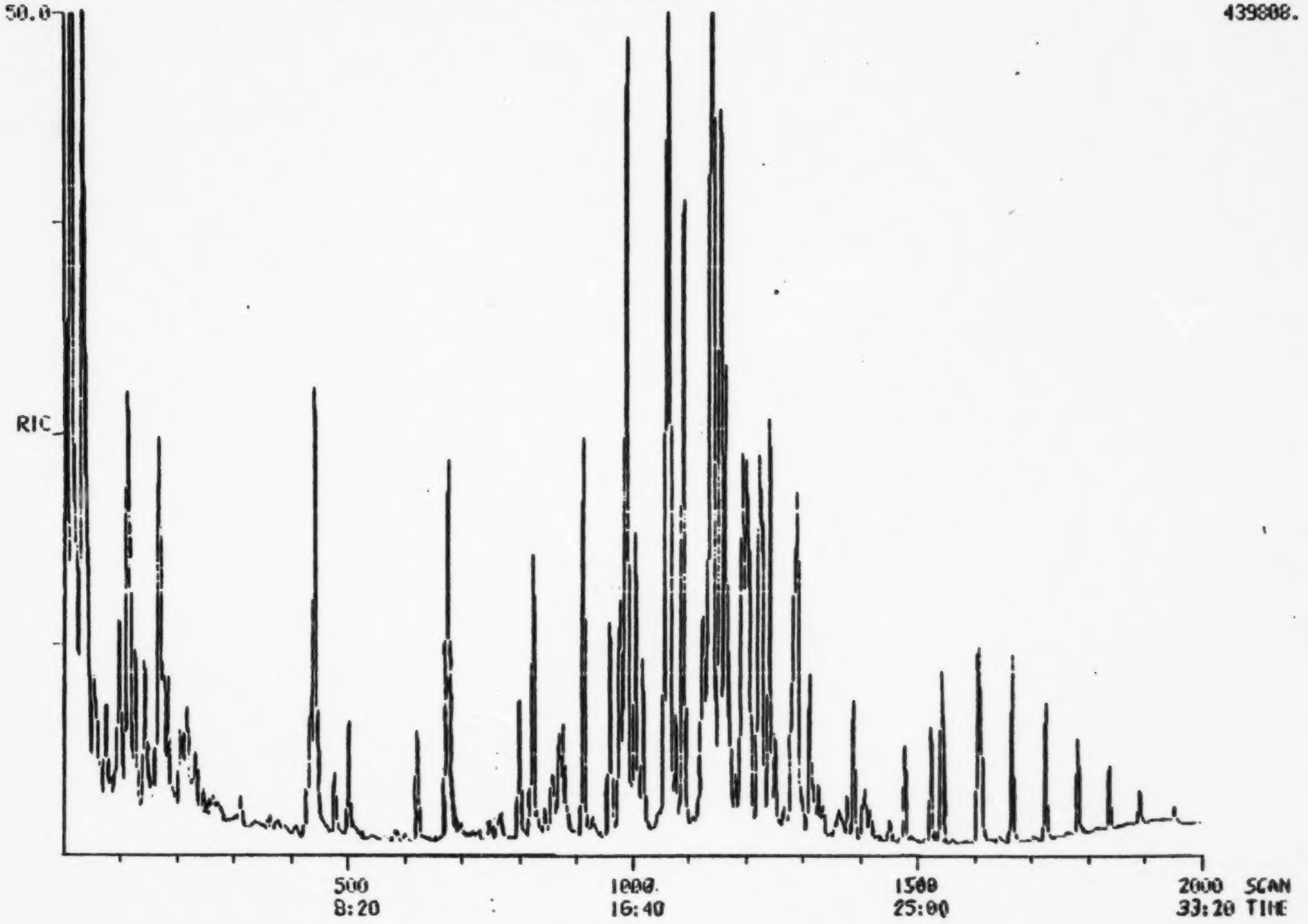
RIC
12/29/79 20:17:00
SAMPLE: 3.0UL KILN ASH DAY#1 BACKGROUND BURN
RANGE: G 1, 1 LABEL: N 0, 4.0 QUAN: A 0, 1.0 BASE: U 20, 3

DATA: KILN1 #1525
CALI: C122979C #3

SCANS 1 TO 1400



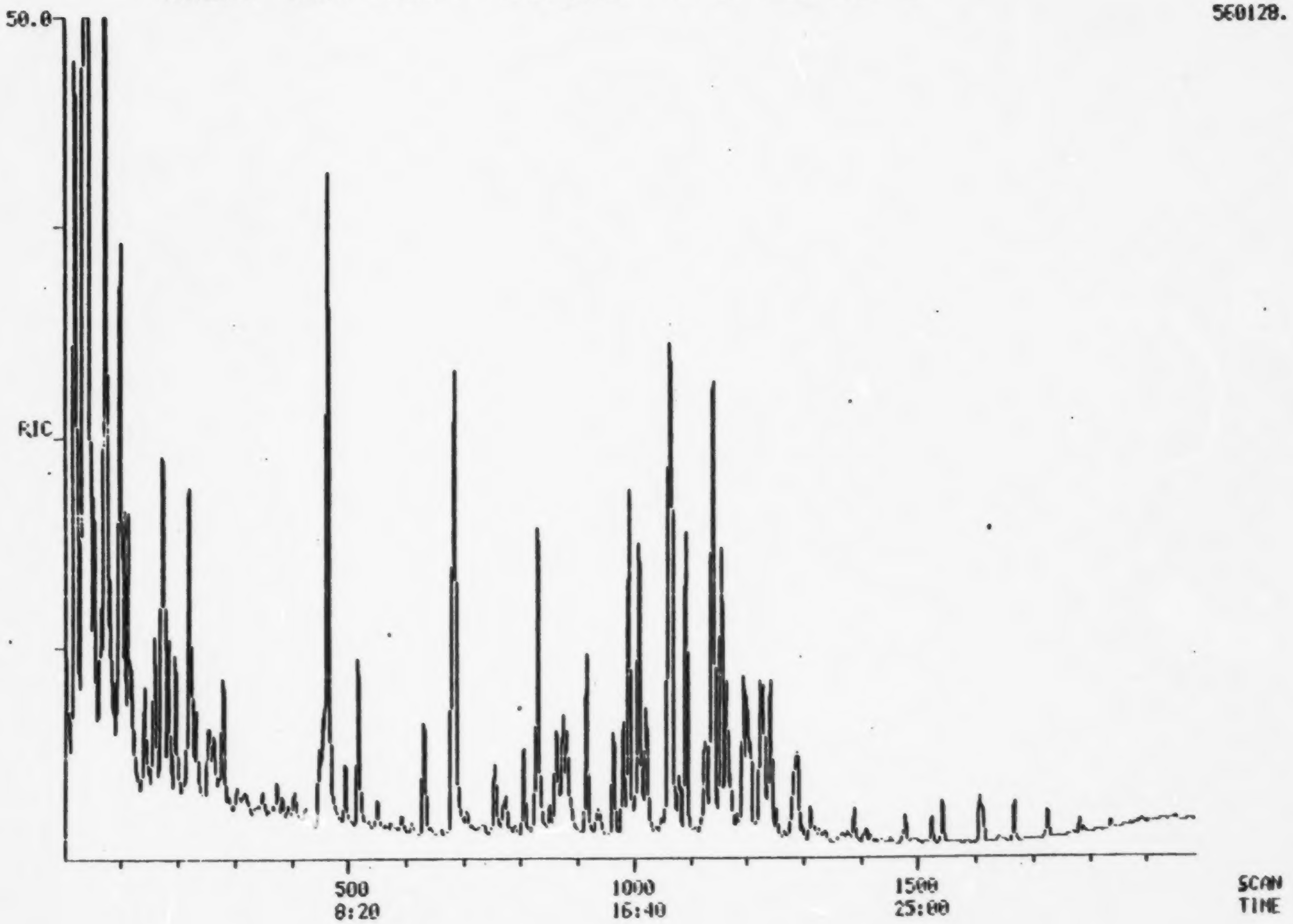
```
RIC                                                       DATA: KILN2 #1           SCANS    1 TO 2000
12/29/79 18:49:00                                         CALI: C122979C #3
SAMPLE: 3.0UL KILN ASH DAY#2 PCB BURN
RANGE: G   1,2000  LABEL: N  1,20.0  QUAN: A  0, 1.0  BASE: U 20,  3
```



RIC
12/29/79 17:45:00
SAMPLE: 3UL KILN ASH DAY#3 PCB BURN
RANGE: G 1,1987 LABEL: H 1,20.0 QUAN: A 0, 1.0 BASE: U 20, 3

DATA: KILN3 #1956
CALI: C122979C #3

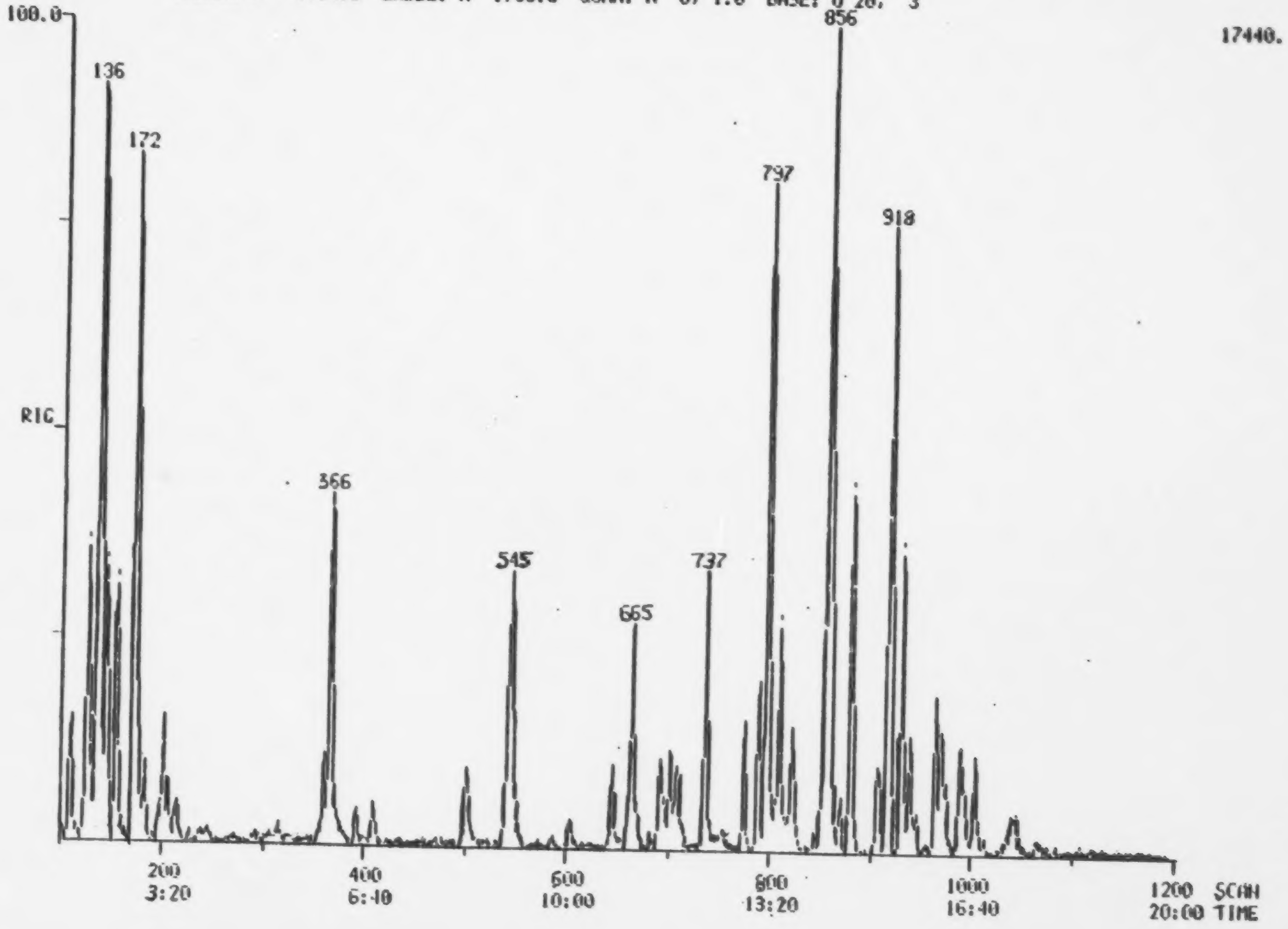
SCANS 1 TO 1987



RIC
12/03/79 15:36:00
SAMPLE: 2.0UL KILN ASH #4 AFTER FLORISIL 6% FRACTION
RANGE: G 1,1408 LABEL: N 1,50.0 QUAN: A 0, 1.0 BASE: U 20, 3

DATA: KILN #797
CALI: C12979 #60

SCANS 100 TO 1200



# APPENDIX B

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VI
6608 Hornwood Drive
Houston, Texas 77074

16 NOV 1979

Mr. Norman W. Flynn
Staff Chemist
Accurex Corporation
485 Clyde Avenue
Mountain View, CA 94042

Dear Mr. Flynn:

I have received your report of analysis of quality assurance samples for PCB content which I supplied to you August 7, 1979. The following are the results reported by you and the expected true values of the samples when prepared according to the directions in my letter to Mr. Steiner.

Sample No. 1 - Reported Composition:

Aroclor 1254; 1.0 ug/liter (ppb)

Expected Actual Composition:

Aroclor 1254; 1.44 ug/liter (ppb)

Sample No. 2 - Reported Composition:

Aroclor 1016; 0.75 ug/liter (ppb)

Expected Actual Composition:

Aroclor 1016; 1.12 ug/liter (ppb)

Sample No. 3 - Reported Composition:

Aroclor 1254; 0.95 ug/l (ppb)

Aroclor 1016; 0.64 ug/l (ppb)

Expected Actual Composition:

Aroclor 1254; 0.87 ug/l (ppb)

Aroclor 1016; 0.39 ug/l (ppb)

Your Aroclor specie identifications are correct in each instance and all quantitative values would be within the range of acceptability based on similar type samples analyzed annually by State and Federal laboratories for proficiency evaluation.

Sincerely,

William D. Langley

William D. Langley, Ph.D.
Chief, Laboratory Section

cc:
Oscar Ramirez, Jr., 6ASA
Charles Gazda, 6ASASC

Background Test 1
10-15-79

## PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68° F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha}\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_{m,avg} + 460}\right) = 46.195 \qquad \alpha = 1.019$$

$$\text{or} \quad Vm_{stack} = \left(\frac{Vm}{\alpha} + Vw_{std}\right)\left(\frac{T_{s,avg} + 460}{T_{m,avg} + 460}\right)\left(\frac{P_m}{P_s}\right) \quad \text{(acf at stack conditions)}$$

=

2. Stack gas moisture condensed at standard conditions (scf)

$$Vw_{std} = 0.04707\ Vl_c \qquad Vl_c = 320 + 16.5$$

$$= 15.839$$

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

$$= 0.255$$

use 0.245 since gases are saturated at 149°F

4. Stack gas dry molecular weight (lb/lb-mole)

$$MW_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

$$= 28.95$$

5. Stack gas molecular weight (lb/lb-mole)

$$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$$

$$= 26.26$$

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

$$= 29.79$$

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7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49\ (C_p)\ (\sqrt{\Delta P})_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s\ MW_s}}$$

$C_p = 0.71$

= 15.1

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60\ (1 - B_{wo})\ Vs_{avg}\ A_s \left(\frac{528}{T_{s,avg} + 460}\right)\left(\frac{P_s}{29.92}\right) = 46{,}358$$

or $Q_a = 60\ Vs_{avg}\ A_s$ (acfm) =

9. Test percent isokinetic

$$\%I = \frac{17.33\ (T_{s,avg} + 460)\ [0.04707\ (W_{lc}) + Vm_{std}]}{\theta\ V_s\ P_s\ D_n^2}$$

= 97.9

10. Particulate matter concentration, gr/scf

$$C_s = 15.432 \frac{M_p}{Vm_{std}} = 0.1404$$

HCl
(0.0324)

or $C_a = 15.432 \frac{M_p}{Vm_{stack}}$ (gr/acf) =

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857\ (Q_s)\ C_s$$

= 55.8

HCl
(12.8)

12. Percent excess air at sampling point

$$\%\ EA = \frac{100\ [\%O_2 - 0.5\ (\%CO)]}{0.264\ [\%N_2 - (\%O_2 - 0.5 \times \%CO)]} = 96.7$$

13. Emission rate of particulate matter, lb/10⁶ Btu

$$E = 2.679 \times 10^4 \left(\frac{M_p}{Vm_{std}}\right) F \left(\frac{20.9}{20.9 - \%O_2}\right)$$

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# PARTICULATE TEST FIELD DATA SHEET

Plant ENSCO
Date 10/15/77
Test Location Stack
Run Number #1 Baseline Control
Stack Diameter inches
Duct Dimensions in x in
Start Time 1140
Operator JARMAN

Barometric Pressure 29.81
Static Pressure -.24
Stack Pressure
Probe Number 15'
Pitot Coefficient
Pitot Number ~~701~~
Meter Box Number 085
Orifice Coefficient .721 α=1.019

Nozzle Size & Number .4978
Molecular Weight
BWO

FILTER DATA

| NUMBER | TARE | FINAL WT |
|---|---|---|
| 1 | | |
| | | |
| | | |

| IMPINGER VOLUMES | | TIME | CO2 | O2 | CO |
|---|---|---|---|---|---|
| 100 | | | 1.8 | 16.6 | |
| 100 | 320 gain | | | | |
| 100 | | | | | |
| 0 | | | | | |
| | | | | | |
| | | | | | |
| SILICA GEL | 16.5 | | | | |

| | SAMPLE POINT | CLOCK TIME | VELOCITY HEAD ΔP in wg | ORIFICE METER ΔH in wg | GAS METER VOLUME FT³ | TEMPERATURES °F | | | | | | | PUMP VACUUM in Hg | √ΔP | Leak Rate |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | STACK | PROBE | IMPINGER | ORGANIC MODULE | OVEN | GAS METER IN | GAS METER OUT | | | |
| Start 1140 | 1 | 0 | .065 | 1.74 | 604.537 | 146 | 269 | | | 269 | 83 | 81 | 6 | .25 | .066 17" |
| | 2 | 5.0 | .084 | 2.23 | 607.92 | 149 | 263 | | | 268 | 83 | 83 | 10 | .29 | |
| | 3 | 10.0 | .065 | 1.74 | 611.72 | 146 | 262 | | | 270 | 84 | 83 | 8 | .25 | |
| | 4 | 15.0 | .11 | 2.94 | 615.38 | 148 | 265 | | | 268 | 84 | 83 | 18 | .33 | |
| | 5 | 20.0 | .105 | 2.80 | 619.50 | 148 | 267 | | | 269 | 84 | 83 | 17 | .32 | |
| END 1210 | 6 | 25.0 | .085 | 2.27 | 624.00 | 149 | 268 | | | 270 | 85 | 84 | 13 | .29 | |
| | off | 30.0 | | | 628.113 | 150 | | | | | ~~84~~ | ~~84~~ | | | Leak Rate |
| | | | | | | | | | | | | | | | 19.5 @ [illegible] |
| Start 1324 | 1 | 30.0 | .08 | 2.12 | 628.495 | 148 | 270 | | | 267 | 79 | 80 | 8 | .28 | Leak rate |
| | 2 | 35.0 | .075 | 1.99 | 633.17 | 151 | 267 | | | 268 | 80 | 80 | 10 | .27 | .021 @ [illegible] |
| | 3 | 40.0 | .08 | 2.11 | 636.87 | 153 | 267 | | | 276 | 80 | 81 | 11 | .28 | |
| | 4 | 45.0 | .10 | 2.44 | 642.23 | 152 | 266 | | | 274 | 80 | 81 | 19 | .32 | |
| | 5 | 50.0 | .07 | 2.31 | 645.16 | 153 | 269 | | | 271 | 80 | 81 | 16 | .3 | |
| | 6 | 55.0 | .08 | 2.14 | 647.23 | 147 | 270 | | | 270 | 80 | 81 | 13 | .28 | |
| | off | 60.0 | | | 653.162 | | | | | | | | | | |
| | | | | | | | | | | | | | | | END LEAK |
| | | | | | | | | | | | | | | | Rate .010 |
| | | | | | | | | | | | | | | | @ 20 in |
| | AVG/TOTAL | | | 2.2 | 48.241 | 149.3<br>149 | | | | | 81.8 | 82 | | .288 | |

Σ 29.896

110

Test 2
10-16-79

# PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68°F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha} \left( \frac{P_b + \frac{\Delta H}{13.6}}{T_{m,avg} + 460} \right) = 44.440$$

$\alpha = 1.019$

or $Vm_{stack} = \left( \frac{Vm}{\alpha} + Vw_{std} \right) \left( \frac{T_{s,avg} + 460}{T_{m,avg} + 460} \right) \left( \frac{P_m}{P_s} \right)$ (acf at stack conditions)

=

2. Stack gas moisture condensed at standard conditions (scf)

$Vw_{std} = 0.04707\ Vl_c$

$Vl_c = 320 + 7.9$

= 15.434

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

= 0.258

4. Stack gas dry molecular weight (lb/lb-mole)

$MW_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$

= 29.13

5. Stack gas molecular weight (lb/lb-mole)

$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$

= 26.26

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

= 29.70

7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49\,(C_p)\,(\sqrt{\Delta P})_{avg}\sqrt{\frac{T_{s,avg} + 460}{P_s\,MW_s}}$$

$C_p = 0.71$

= 14.8

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60\,(1 - B_{wo})\,Vs_{avg}\,A_s\left(\frac{528}{T_{s,avg} + 460}\right)\left(\frac{P_s}{29.92}\right) = 43,883$$

or $Q_a = 60\,Vs_{avg}\,A_s$ (acfm) =

9. Test percent isokinetic

$$\%I = \frac{17.33\,(T_{s,avg} + 460)\;[0.04707\,(W_{lc}) + Vm_{std}]}{\theta\,V_s\,P_s\,D_n^2}$$

= 96.8

10. Particulate matter concentration, gr/scf

HCl

$$C_s = 15.432\,\frac{M_p}{Vm_{std}} = 0.4692$$

(0.0594)

or $C_a = 15.432\,\dfrac{M_p}{Vm_{stack}}$ (gr/acf) =

11. Emission rate of particulate matter, lb/hr

HCl

$$ER = 0.00857\,(Q_s)\,C_s$$

= 176.5

(22.3)

12. Percent excess air at sampling point

$$\%\,EA = \frac{100\,[\%O_2 - 0.5\,(\%CO)]}{0.264\,[\%N_2 - (\%O_2 - 0.5 \times \%CO)]} = 103.7$$

13. Emission rate of particulate matter, lb/$10^6$ Btu

$$E = 2.679 \times 10^{4}\left(\frac{M_p}{Vm_{std}}\right)F\left(\frac{20.9}{20.9 - \%O_2}\right)$$

# PARTICULATE TEST FIELD DATA SHEET

Plant ENSCO
Date 10/16/79
Test Location Stack
Run Number #2
Stack Diameter inches
Duct Dimensions in x in
Start Time 1218
Operator JARMAN

Barometric Pressure 29.72
Static Pressure -.24"
Stack Pressure 29.70
Part/HCl Probe Number 15'
Pitot Coefficient .71
Pitot Number
Meter Box Number 085 α=1.019
Orifice Coefficient ± 1.701

Nozzle Size & Number .4978 ~~.500~~
Molecular Weight
BWO

FILTER DATA

| NUMBER | TARE | FINAL WT |
|---|---|---|
| | | |
| | | |
| | | |

| IMPINGER VOLUMES | | TIME | CO₂ | O₂ | CO |
|---|---|---|---|---|---|
| | 330 ml gain | | 2.8 | 17.2 | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| SILICA GEL | | 7.9 g gain | | | |
| | 100 g @ 0020 | | | | |

Start 1218

| SAMPLE POINT | CLOCK TIME | VELOCITY HEAD ΔP in wg | ORIFICE METER ΔH in wg | GAS METER VOLUME FT³ | TEMPERATURES °F STACK | PROBE | IMPINGER | ORGANIC MODULE | OVEN | GAS METER IN | OUT | PUMP VACUUM in Hg | √ΔP | Leak Rate .018 @ 15 Hg pitot ok |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | .11 | 2.96 | 655.741 | 159 | 271 | | | 280 | 85 | 85 | 13 | .33 | |
| 2 | 5 | .11 | 2.96 | 660.10 | 160 | 269 | | | 279 | 85 | 85 | 15 | .33 | |
| 3 | 10 | .11 | 2.97 | 664.91 | 158 | 270 | | | 272 | 85 | 85 | 19 | .33 | |
| 4 | 15 | .06 | 1.62 | 669.13 | 157 | 280 | | | 279 | 86 | 86 | 2.5 | 24 | |
| 5 | 20 | .065 | 1.76 | 672.67 | 158 | 281 | | | 282 | 86 | 86 | 8 | .25 | |
| 6 | 25 | .06 | 1.61 | 676.21 | 160 | 280 | | | 283 | 85 | 86 | 8 | 24 | |
| OFF | 30 | | | | ~~159~~ | ~~281~~ | | | | | | | | |
| | | | | | | | | | | | | | | |
| ~~7~~ 6 | ~~5~~ 30 | .055 | 1.49 | 676.21 | 158 | 280 | | | 281 | 87 | 86 | 7 | .23 | |
| ~~2~~ 5 | ~~10~~ 35 | .06 | 1.62 | 682.63 | 158 | 282 | | | 282 | 87 | 86 | 8 | .24 | |
| ~~3~~ 4 | ~~15~~ 40 | .06 | 1.62 | 685.96 | 159 | 284 | | | 293 | 88 | 87 | 8.5 | 27 | |
| ~~4~~ 3 | ~~20~~ 45 | .09 | 2.42 | 689.19 | 161 | 283 | | | 287 | 88 | 87 | 15 | .3 | |
| ~~5~~ 2 | ~~25~~ 50 | .10 | 2.70 | 693.35 | 159 | 284 | | | 286 | 88 | 87 | 16 | ~~.31~~ | .32 |
| ~~6~~ 1 | ~~5~~ 55 | .10 | 2.71 | 697.85 | 160 | 282 | | | 284 | 88 | 88 | 18 | ~~.31~~ | .32 |
| OFF | 60.7 | | | 702.674 | | | | | | | | | | 60.9 min |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | END LEAK |
| | | | | | | | | | | | | | | RATE .02 @ |
| | | | | | | | | | | | | | | 19 Hg |
| AVG/TOTAL | | | 2.20 | 46.933<br>30.612 | 158.9<br>159 | | | | | 86.5 | 86.1<br>84 | | .28 | |

END Time 1330

Form LED 021 1-9

Test 3
10-17-79

## PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68° F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha} \left( \frac{P_b + \frac{\Delta H}{13.6}}{T_{m,avg} + 460} \right) = 44.252$$

$\alpha = 1.019$

$$\text{or } Vm_{stack} = \left( \frac{Vm}{\alpha} + Vw_{std} \right) \left( \frac{T_{s,avg} + 460}{T_{m,avg} + 460} \right) \left( \frac{P_m}{P_s} \right) \cdot \text{(acf at stack conditions).}$$

=

2. Stack gas moisture condensed at standard conditions (scf)

$Vw_{std} = 0.04707\ Vl_c$

$Vl_c = 319 + 17.1$

= 15.820

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

= 0.263

4. Stack gas dry molecular weight (lb/lb-mole)

$MW_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$

= 29.11

5. Stack gas molecular weight (lb/lb-mole)

$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$

= 26.19

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

= 29.76

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7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49\,(C_p)\,(\sqrt{\Delta P})_{avg}\sqrt{\frac{T_{s,avg} + 460}{P_s\,MW_s}}$$

$C_p = 0.71$

= 14.8

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60\,(1 - B_{wo})\,Vs_{avg}\,A_s\left(\frac{528}{T_{s,avg} + 460}\right)\left(\frac{P_s}{29.92}\right) =$$ 43,700

or $Q_a = 60\,Vs_{avg}\,A_s$ (acfm) =

9. Test percent isokinetic

$$\%I = \frac{17.33\,(T_{s,avg} + 460)\ [0.04707\,(W_{lc}) + Vm_{std}]}{\theta\,V_s\,P_s\,D_n^2}$$

= 98.3

10. Particulate matter concentration, gr/scf

HCl

$$C_s = 15.432\,\frac{M_p}{Vm_{std}} =$$ 0.2862

(0.1559)

or $C_a = 15.432\,\frac{M_p}{Vm_{stack}}$ (gr/acf) =

11. Emission rate of particulate matter, lb/hr

HCl

$$ER = 0.00857\,(Q_s)\,C_s$$

(58.3)

= 107.3

12. Percent excess air at sampling point

$$\%\,EA = \frac{100\,[\%O_2 - 0.5\,(\%CO)]}{0.264\,[\%N_2 - (\%O_2 - 0.5 \times \%CO)]} =$$ 98.2

13. Emission rate of particulate matter, lb/10⁶ Btu

$$E = 2.679 \times 10^4\left(\frac{M_p}{Vm_{std}}\right)F\left(\frac{20.9}{20.9 - \%O_2}\right)$$

# PARTICULATE TEST FIELD DATA SHEET

Plant ENSCO
Date 10/17/79
Test Location Stack
Run Number #3 ~~PCB~~ Part. HCL
Stack Diameter inches
Duct Dimensions in x in
Start Time 1317
Operator JARMAN

Barometric Pressure 29.78
Static Pressure .22
Stack Pressure 29.76
Probe Number 15'
Pitot Coefficient .71
Pitot Number 12
Meter Box Number 85
Orifice Coefficient .701 α = 1.019

Nozzle Size & Number .4978
Molecular Weight
BWO

FILTER DATA

| NUMBER | TARE | FINAL WT |
|---|---|---|
| | | |
| | | |
| | | |

| IMPINGER VOLUMES | | TIME | CO₂ | O₂ | CO |
|---|---|---|---|---|---|
| | | | 2.8 | 16.6 | |
| | | | | | |
| | 886.1 | 4min | | | |
| | | | | | |
| 314 | | | | | |
| SILICA GEL | | | | | |
| | 17.1 | | | | |

| | SAMPLE POINT | CLOCK TIME | VELOCITY HEAD ΔP in wg | ORIFICE METER ΔH in wg | GAS METER VOLUME FT³ | TEMPERATURES °F STACK | PROBE | IMPINGER | ORGANIC MODULE | OVEN | GAS METER IN | GAS METER OUT | PUMP VACUUM in Hg | √ΔP | LEAK RATE .007 @ 18 hg Pitot ok |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start 1317 | 1 6 | 0 | .09 | 2.73 | 703.227 | 158 | 264 | | | 266 | 89 | 90 | 10 | .3 | |
| | 2 5 | 5 | .11 | 2.98 | 707.58 | 159 | 275 | | | 280 | 86 | 90 | 17 | .33 | |
| | 3 4 | 10 | .09 | 2.43 | 712.27 | 159 | 272 | | | 281 | 85 | 89 | 12 | .3 | |
| | 4 3 | 15 | .06 | 1.62 | 716.51 | 158 | 274 | | | 282 | 84 | 88 | 7 | .24 | |
| | 5 2 | 20 | .07 | 1.89 | 719.89 | 157 | 278 | | | 281 | 82 | 87 | 8 | .26 | |
| | 6 1 | 25 | .06 | 1.6 | 723.67 | 159 | 280 | | | 283 | 79 | 80 | 9 | .24 | |
| END 1347 | OFF | 30 | | | 727.165 | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| Start 1610 | 1 6 | 30 | .07 | 1.87 | 727.165 | 158 | 271 | | | 261 | 79 | 81 | 7 | .26 | |
| | 2 5 | 35 | .065 | 1.74 | 730.80 | 160 | 271 | | | 264 | 80 | 79 | 7 | .25 | |
| | 3 4 | 40 | .04 | 1.06 | 734.32 | 159 | 268 | | | 263 | 80 | 78 | 4 | .2 | |
| | 4 3 | 45 | .095 | 2.53 | 737.16 | 160 | 272 | | | 263 | 78 | 77 | 11 | ~~.295~~ .30 | 0.31 |
| | 5 2 | 50 | .10 | 2.66 | 740.17 | 159 | 269 | | | 265 | 78 | 77 | 11 | .32 | ← stopped to |
| | 6 1 | 55 | .09 | 2.39 | 745.41 | 158 | 268 | | | 265 | 77 | 77 | 11 | .3 | re-position probe & oven |
| | OFF | 60 | | | 749.521 | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | END LEAK Rat | | |
| | | | | | | | | | | | | | .010 @ 18hg | | |
| | | | | 2.13 | ✓ | 158.6 | | | | | | 82.9 | | | |
| | AVG/TOTAL | | | 2.12 | 46.294 | 159 | | | | | 81.4 | 83 | | .279 | 0.280 |

30.641

Form EED 021 1 79

## PARTICULATE CALCULATIONS

Test 4
10-18-79

1. Volume of dry gas sampled at standard conditions, 68°F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha}\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_{m,avg} + 460}\right) = 43.676$$

$\alpha = 1.019$

or $Vm_{stack} = \left(\frac{Vm}{\alpha} + Vw_{std}\right)\left(\frac{T_{s,avg} + 460}{T_{m,avg} + 460}\right)\left(\frac{P_m}{P_s}\right)$ (acf at stack conditions)

=

2. Stack gas moisture condensed at standard conditions (scf)

$Vw_{std} = 0.04707\ Vl_c$

$= 18.508$

$V_{lc} = 375 + 16.2$

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

$= 0.298$

4. Stack gas dry molecular weight (lb/lb-mole)

$MW_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$

$= 29.10$

5. Stack gas molecular weight (lb/lb-mole)

$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$

$= 25.79$

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

$= 29.47$

7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49\ (C_p)\ (\sqrt{\Delta P})_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s\ MW_s}}$$

$C_p = 0.71$

= 15.5

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60\ (1 - B_{wo})\ Vs_{avg}\ A_s \left(\frac{528}{T_{s,avg} + 460}\right)\left(\frac{P_s}{29.92}\right) = \quad 43,208$$

or $Q_a = 60\ Vs_{avg}\ A_s$ (acfm) =

9. Test percent isokinetic

$$\%I = \frac{17.33\ (T_{s,avg} + 460)\ \ [0.04707\ (W_{lc}) + Vm_{std}]}{\theta\ V_s\ P_s\ D_n^2}$$

= 98.3

10. Particulate matter concentration, gr/scf

HCl

$$C_s = 15.432\ \frac{M_p}{Vm_{std}} = \quad 0.4233$$

(0.1113)

or $C_a = 15.432\ \dfrac{M_p}{Vm_{stack}}$ (gr/acf) =

11. Emission rate of particulate matter, lb/hr

HCl

$$ER = 0.00857\ (Q_s)\ C_s$$

= 156.7

(41.2)

12. Percent excess air at sampling point

$$\%\ EA = \frac{100\ [\%O_2 - 0.5\ (\%CO)]}{0.264\ [\%N_2 - (\%O_2 - 0.5 \times \%CO)]} = \quad 89.8$$

13. Emission rate of particulate matter, lb/$10^6$ Btu

$$E = 2.679 \times 10^{4} \left(\frac{M_p}{Vm_{std}}\right) F \left(\frac{20.9}{20.9 - \%O_2}\right)$$

# PARTICULATE TEST FIELD DATA SHEET

Plant ENSCO
Date 10/18/79
Test Location Stack
Run Number # 4 Part HCL
Stack Diameter inches
Duct Dimensions in x in
Start Time 1054
Operator JARMAN

Barometric Pressure 29.49
Static Pressure -.22
Stack Pressure 29.47
Probe Number 10'
Pitot Coefficient .71
Pitot Number .0
Meter Box Number 285
Orifice Coefficient .701 K=1.019

Nozzle Size & Number
Molecular Weight
BWO

FILTER DATA

| NUMBER | TARE | FINAL WT |
|---|---|---|
| | | |
| | | |
| | | |

| IMPINGER VOLUMES | | TIME | CO₂ | O₂ | CO |
|---|---|---|---|---|---|
| | | | 3.0 | 15.6 | |
| | | | | | |
| | 143.2 | 9 min | | | |
| | | | | | |
| 375 | | | | | |
| | | | | | |
| SILICA GEL | | | | | |
| | 14.2 | | | | |

| | SAMPLE POINT | CLOCK TIME | VELOCITY HEAD ΔP in wg | ORIFICE METER ΔH in wg | GAS METER VOLUME FT³ | TEMPERATURES °F STACK | PROBE | IMPINGER | ORGANIC MODULE | OVEN | GAS METER IN | GAS METER OUT | PUMP VACUUM in Hg | √ΔP | Leak Rate .005 @ 15 in pitot ok |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Start 1054 | 6 | 0 | .10 | 2.66 | 49.724 | 159 | 275 | | | 277 | 87 | 89 | 10 | .32 | |
| | 5 | 5 | .11 | 2.42 | | 160 | 271 | | | 278 | 88 | 89 | 16 | .33 | |
| | 4 | 10 | .09 | 2.39 | 58.35 | 157 | 272 | | | 277 | 89 | 89 | 14 | .3 | |
| | 3 | 15 | .06 | 1.33 | 62.17 | 159 | 269 | | | 278 | 90 | 91 | 5 | .22 | |
| | 2 | 20 | .055 | 1.47 | 65.71 | 158 | 267 | | | 277 | 90 | 90 | 5 | .23 | |
| | 1 | 25 | .06 | 1.59 | 68.82 | 158 | 263 | | | 278 | 88 | 91 | 6 | .24 | |
| End 1124 | OFF | 30 | | | 72.091 | | | | | | | | | | |
| | | | | | 22.362 | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| Start 1215 | 6 | 30 | .11 | 2.93 | 72.239 | 160 | 268 | | | 277 | 92 | 92 | 11 | .33 | |
| | 5 | 35 | .115 | 3.06 | 76.83 | 160 | 269 | | | 277 | 91 | 92 | 13 | .34 | |
| | 4 | 40 | .10 | 2.66 | | 159 | 271 | | | 274 | 91 | 92 | 11 | .32 | |
| | 3 | 45 | .06 | 1.59 | 85.91 | 161 | 270 | | | 277 | 92 | 92 | 6 | .24 | |
| | 2 | 50 | .075 | 2.0 | 88.19 | 160 | 272 | | | 279 | 93 | 93 | 8 | .27 | |
| | 1 | 55 | .08 | 2.13 | 92.87 | 159 | 274 | | | 278 | 93 | 92 | 8 | .28 | |
| End 1245 | OFF | 60 | | | 96.737 | | | | | | | | | | END [illegible] |
| | | | | | | | | | | | | | | | [illegible] |
| | | | | | | | | | | | | | | | [illegible] |
| | | | | | | | | | | | | | | | |
| | | | | 2.22 | ✓ | 159.3 | | | | | | | | | |
| | AVG/TOTAL | | | 2.23 | 46.860 | 159 | | | | | 90.5 | 91 | | .29 | |

29.744

Form FED 021 [illegible]

PCB/RCL Baseline
10/15/79

## PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68° F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha} \left( \frac{P_b + \frac{\Delta H}{13.6}}{T_{m,avg} + 460} \right) = 145.983 \qquad \alpha = 1.007$$

$$\text{or} \quad Vm_{stack} = \left( \frac{Vm}{\alpha} + Vw_{std} \right) \left( \frac{T_{s,avg} + 460}{T_{m,avg} + 460} \right) \left( \frac{P_m}{P_s} \right) \quad \text{(acf at stack conditions)}$$

=

2. Stack gas moisture condensed at standard conditions (scf)

$$Vw_{std} = 0.04707\ Vl_c \qquad Vl_c = 820 + 20.5$$

$$= 39.562$$

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

$$= 0.213$$

4. Stack gas dry molecular weight (lb/lb-mole)

$$MW_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$$

$$= 28.95$$

5. Stack gas molecular weight (lb/lb-mole)

$$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$$

$$= 26.61$$

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

$$= 29.79$$

120

7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49\,(C_p)\,(\sqrt{\Delta P})_{avg}\sqrt{\frac{T_{s,avg} + 460}{P_s\,MW_s}}$$

$C_p = 0.67$

= 18.2

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60\,(1 - B_{wo})\,Vs_{avg}\,A_s\left(\frac{528}{T_{s,avg} + 460}\right)\left(\frac{P_s}{29.92}\right) =$$

58 030

or $Q_a = 60\,Vs_{avg}\,A_s$ (acfm) =

9. Test percent isokinetic

$$\%I = \frac{17.33\,(T_{s,avg} + 460)\;[0.04707\,(W_{lc}) + Vm_{std}]}{\theta\,V_s\,P_s\,D_n^2}$$

=

10. Particulate matter concentration, gr/scf

$$C_s = 15.432\,\frac{M_p}{Vm_{std}} =$$

or $C_a = 15.432\,\dfrac{M_p}{Vm_{stack}}$ (gr/acf) =

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857\,(Q_s)\,C_s$$

=

12. Percent excess air at sampling point

$$\%\,EA = \frac{100\,[\%O_2 - 0.5\,(\%CO)]}{0.264\,[\%N_2 - (\%O_2 - 0.5 \times \%CO)]} =$$

13. Emission rate of particulate matter, lb/$10^6$ Btu

$$E = 2.679 \times 10^{4}\left(\frac{M_p}{Vm_{std}}\right)F\left(\frac{20.9}{20.9 - \%O_2}\right)$$

all = $\frac{T_m}{P_m}$ or K $K(N)^4 =$ 12.531

# PARTICULATE TEST FIELD DATA SHEET

Plant EnCCO
Date 10-15-79
Test Location Stack
Run Number 1 Baseline PCG/PCL
Stack Diameter inches
Duct Dimensions in x in ——
Start Time 1134
Operator M. Chips

Barometric Pressure 29.81
Static Pressure -.24
Stack Pressure
Probe Number —
Pitot Coefficient .67
Pitot Number —
Meter Box Number 842 1.007
Orifice Coefficient .683

Nozzle Size & Number .407
Molecular Weight
BWO

FILTER DATA

| NUMBER | TARE | FINAL WT |
|---|---|---|
| | | |
| | | |
| | | |

| IMPINGER VOLUMES | | TIME | $CO_2$ | $O_2$ | CO |
|---|---|---|---|---|---|
| 100 | | | 1.8 | 16.6 | |
| 100 | 820 | | | | |
| — | gain | | | | |
| | | | | | |
| | | | | | |
| SILICA GEL | | | | | |
| 200cc | 20.5 | | | | |

| | SAMPLE POINT | CLOCK TIME | VELOCITY HEAD ΔP in wg | ORIFICE METER ΔH in wg | GAS METER VOLUME FT³ | TEMPERATURES °F STACK | PROBE | IMPINGER | ORGANIC MODULE | OVEN | GAS METER IN | GAS METER OUT | PUMP VACUUM in Hg | $\sqrt{\Delta P}$ | initial/ leak rate | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| West Port | 1 in | 0 | .17 | 1.85 | 276.233 | 150 | 270 | | | | 71 | 71 | 14 | .412 | 0.017 at | 1134 |
| | 2 | 20 | .16 | 1.77 | 290.37 | 147 | 269 | | | | 75 | 77 | 15 | .400 | 15" Hg | |
| | 3 out | 40 | .12 | 1.34 | 304.12 | 145 | 257 | | | | 81 | 83 | 12 | .346 | 0.007 at | 1234 |
| | end | 60 | | | 316.293 | | | | | | | | | | 15" Hg | |
| | | | | | [illegible] | | | | | | | | | | | |
| South Port | 1 in | 60 | .12 | 1.33 | 316.493 | 149 | 269 | | | | 77 | 78 | 11 | .346 | 0.014 at 18" Hg | 1305 |
| | 2 | 80 | .12 | 1.32 | 328.38 | 152 | 257 | | | | 79 | 79 | 11 | .346 | | |
| | 3 out | 100 | .09 | 1.01 | 340.17 | 148 | 269 | | | | 83 | 81 | 10 | .300 | | 1405 |
| | End | 120 | | | 350.559 | | | | | | | | | | 0.009 at 11" Hg | |
| East Port | 1 in | 120 | .15 | 1.65 | 350.844 | 157 | 271 | 1429 | | | 80 | 80 | 14 | .387 | 0.017 at 18" | Hg |
| | 2 | 140 | .15 | 1.65 | 364.22 | 157 | 278 | | | | 82 | 80 | 14 | .387 | | |
| | 3 out | 160 | .15 | 1.65 | 377.54 | 157 | 280 | | | | 81 | 80 | 16 | .387 | | |
| | End | 180 | | | 390.859 | | | 1540 | | | | | | | 0.015 at 18" Hg | |
| North Port | 1 in | 180 | .13 | 1.42 | 391.084 | 156 | 290 | | 1611 | | 77 | 76 | 12 | .360 | 0.00 at 12" Hg | |
| | 2 | 200 | .12 | 1.32 | 403.44 | 154 | 283 | | | | 77 | 77 | 12 | .346 | | |
| | 3 out | 220 | .11 | 1.20 | 415.75 | 155 | 286 | | | | 77 | 77 | 12 | .332 | | |
| | END | 240 | | | 426.860 | | | | | | | | | | 0.010 at 12" Hg | |
| | AVG/TOTAL | | | 1.46 | 149.918 | 152.2 | | | | | 78.3<br>78.2 | 78.2<br>77 | | .362 | | |

Form EED 021 1/79

122

PCB #2
10/16/79

## PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68° F, 29.92 inch Hg (scf)

$$Vm_{std} \quad 17.64 \frac{Vm}{\alpha}\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_{m,avg} + 460}\right) = 101.507 \qquad \alpha = 1.007$$

$$\text{or} \quad Vm_{stack} = \left(\frac{Vm}{\alpha} + Vw_{std}\right)\left(\frac{T_{s,avg} + 460}{T_{m,avg} + 460}\right)\left(\frac{P_m}{P_s}\right) \quad \text{(acf at stack conditions)}$$

=

2. Stack gas moisture condensed at standard conditions (scf)

$Vw_{std} = 0.04707\ Vl_c$ $\qquad$ $Vl_c = 880 + 18.0 + 11.2$

= 42.796

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

= 0.297

4. Stack gas dry molecular weight (lb/lb-mole)

$MW_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$

= 29.13

5. Stack gas molecular weight (lb/lb-mole)

$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$

= 25.82

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

= 29.70

123

7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49\ (C_p)\ (\sqrt{\Delta P})_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s\ MW_s}}$$ $C_p = 0.67$

$= 15.8$

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60\ (1 - B_{wo})\ Vs_{avg}\ A_s \left(\frac{528}{T_{s,avg} + 460}\right)\left(\frac{P_s}{29.92}\right) =$$ 44488

or $Q_a = 60\ Vs_{avg}\ A_s$ (acfm) =

9. Test percent isokinetic

$$\%I = \frac{17.33\ (T_{s,avg} + 460)\ \ [0.04707\ (W_{lc}) + Vm_{std}]}{\theta\ V_s\ P_s\ D_n^2}$$

=

10. Particulate matter concentration, gr/scf

$$C_s = 15.432 \frac{M_p}{Vm_{std}} =$$

or $C_a = 15.432 \dfrac{M_p}{Vm_{stack}}$ (gr/acf) =

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857\ (Q_s)\ C_s$$

=

12. Percent excess air at sampling point

$$\%\ EA = \frac{100\ [\%O_2 - 0.5\ (\%CO)]}{0.264\ \ \%N_2 - (\%O_2 - 0.5 \times \%CO)} =$$

13. Emission rate of particulate matter, lb/10⁶ Btu

$$E = 2.679 \times 10^4 \left(\frac{M_p}{Vm_{std}}\right) F \left(\frac{20.9}{20.9 - \%O_2}\right)$$

# PARTICULATE TEST FIELD DATA SHEET

ΔH = 8.859 $\frac{3m}{75}$ ΔP.

Plant ENSCO
Date 10-15-79
Test Location Stack
Run Number 2 1st PCB Burn
Stack Diameter inches
Duct Dimensions in x in
Start Time 1214
Operator M. Chips

Barometric Pressure 29.72
Static Pressure
Stack Pressure 29.70
Probe Number
Pitot Coefficient .67
Pitot Number
Meter Box Number 84 α = 1.007
Orifice Coefficient .683

Nozzle Size & Number .371
Molecular Weight
BWO

FILTER DATA

| NUMBER | TARE | FINAL WT |
|---|---|---|
| | | |
| | | |
| | | |

| IMPINGER VOLUMES | | TIME | CO₂ | O₂ | CO |
|---|---|---|---|---|---|
| 10' | | | 2.8 | 17.2 | |
| 100 | ~~[illegible]~~ 880 ml | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| SILICA GEL | | | | | |
| 200 | 18.0 + 16.2 | | | | |

| | SAMPLE POINT | CLOCK TIME | VELOCITY HEAD ΔP in wg | ORIFICE METER ΔH in wg | GAS METER VOLUME FT³ | TEMPERATURES °F STACK | PROBE | IMPINGER | ORGANIC MODULE | OVEN | GAS METER IN | GAS METER OUT | PUMP VACUUM in Hg | √ΔP | initial Leak Rate 0.015 at 18" Hg | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| South Port | 1 in | 0 | .10 | 0.77 | 427.084 | 158 | 263 | | | | 80 | 81 | 7 | .316 | | 1214 |
| | 2 | 20 | .11 | 0.851 | 436.37 | 158 | 290 | | | | 79 | 80 | 8 | .332 | | |
| | 3 out | 40 | .10 | 0.77 | 446.10 | 157 | 289 | | | | 80 | 81 | 8 | .316 | | |
| | END | 60 | | | 455.459 | | | | | | | | | | 0.010 at 9" Hg | 1314 |
| | | | | | | | | | | | | | | | | |
| East Port | 1 in | 10 | .14 | 1.08 | 455.753 | 160 | 243 | | | | 80 | 80 | 8 | .374 | .010 at 18" Hg | 1340 |
| | 2 | 80 | .15 | 1.17 | 466.67 | 157 | 274 | | | | 83 | 83 | 9 | .357 | | |
| | 3 out | 100 | .12 | .438 | 477.90 | 160 | 287 | | | | 87 | 87 | 8 | .346 | .017 at 8" Hg | 1440 |
| | End | 120 | | | 487.903 | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| North Port | 1 in | 120 | .07 | 0.55 | 488.213<br>~~488.972~~ | 158 | 285 | 1511 | | | 86 | 85 | 4 | .265 | .010 at 16" Hg | 1511 |
| | 2 | 140 | .07 | 0.55 | 495.64 | 160 | 284 | | | | 88 | 87 | 5 | .265 | | |
| 8.859 | 3 out | 180 | .07 | 0.55 | 502.58 | 158 | 283 | 1555 | | | 91 | 90 | 5 | .215 | .006 at 8" Hg | |
| | END | 180 | | | 509.582 | | | 1615 | | | | | | | | |
| | | | | | | | | | | | | | | | | |
| West Port | 1 in | 180 | .09 | 0.71 | 509.916 | 158 | 284 | 1642 | | | 90 | 91 | 5 | .300 | .014 at 10" Hg | |
| | 2 | 200 | .07 | 0.55 | 518.67 | 157 | 276 | | | | 88 | 88 | 5 | .265 | | |
| | 3 out | 220 | .07 | 0.55 | 526.35 | 158 | 271 | 1742 | | | 87 | 87 | 6 | .265 | | |
| | END | 240 | | | 534.085 | | | | | | | | | | .011 at 9" Hg | |
| | | | | | | | | | | | 84.9 | 85 | | | | |
| | AVG/TOTAL | | | .75 | 106.063 | 158.2 | | | | | | 85 | | .308 | | |

PCB #2
10/17/79

## PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68° F, 29.92 inch Hg (scf)

$$Vm_{std} = 17.64 \frac{Vm}{\alpha}\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_{m,avg} + 460}\right) = 106.062 \qquad \alpha = 1.007$$

$$\text{or } Vm_{stack} = \left(\frac{Vm}{\alpha} + Vw_{std}\right)\left(\frac{T_{s,avg} + 460}{T_{m,avg} + 460}\right)\left(\frac{P_m}{P_s}\right) \quad \text{(acf at stack conditions)}$$

$=$

2. Stack gas moisture condensed at standard conditions (scf)

$Vw_{std} = 0.04707\ Vl_c$ $\qquad Vl_c = 790 + 16.5 + 15.6$

$= 38.696$

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

$= 0.267$

4. Stack gas dry molecular weight (lb/lb-mole)

$MW_d = 0.44\ (\%CO_2) + 0.32\ (\%O_2) + 0.28\ (\%N_2 + \%CO)$

$= 29.11$

5. Stack gas molecular weight (lb/lb-mole)

$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$

$= 26.15$

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

$= 29.76$

7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49\ (C_p)\ (\sqrt{\Delta P})_{avg} \sqrt{\frac{T_{s,avg} + 460}{P_s\ MW_s}}$$

$C_p = 0.67$

= 15.6

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60\ (1 - B_{wo})\ Vs_{avg}\ A_s \left(\frac{528}{T_{s,avg} + 460}\right)\left(\frac{P_s}{29.92}\right) =$$

46,278

or $Q_a = 60\ Vs_{avg}\ A_s$ (acfm) =

9. Test percent isokinetic

$$\%I = \frac{17.33\ (T_{s,avg} + 460)\ \ [0.04707\ (W_{lc}) + Vm_{std}]}{\theta\ V_s\ P_s\ D_n^2}$$

=

10. Particulate matter concentration, gr/scf

$$C_s = 15.432 \frac{M_p}{Vm_{std}} =$$

or $C_a = 15.432 \dfrac{M_p}{Vm_{stack}}$ (gr/acf) =

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857\ (Q_s)\ C_s$$

=

12. Percent excess air at sampling point

$$\%\ EA = \frac{100\ [\%O_2 - 0.5\ (\%CO)]}{0.264\ \ \%N_2 - (\%O_2 - 0.5 \times \%CO)} =$$

13. Emission rate of particulate matter, lb/$10^6$ Btu

$$E = 2.679 \times 10^{4} \left(\frac{M_p}{Vm_{std}}\right) F \left(\frac{20.9}{20.9 - \%O_2}\right)$$

# PARTICULATE TEST FIELD DATA SHEET

Plant ENSCO
Date 10-17-79
Test Location STACK
Run Number 3 2nd PCB Burn
Stack Diameter inches
Duct Dimensions in x in
Start Time
Operator M. Chris

Barometric Pressure 29.78
Static Pressure -.22 "H₂O
Stack Pressure
Probe Number
Pitot Coefficient .67
Pitot Number P-13
Meter Box Number 84 α=1.007
Orifice Coefficient .683

Nozzle Size & Number .371
Molecular Weight
BWO

FILTER DATA

| NUMBER | TARE | FINAL WT |
|---|---|---|
| | | |
| | | |
| | | |

| IMPINGER VOLUMES | | TIME | CO₂ | O₂ | CO |
|---|---|---|---|---|---|
| 100 | | | 2.8 | 16.6 | |
| 100 | | | | | |
| | | | | | |
| 290 | | | | | |
| | | | | | |
| SILICA GEL | | | | | |
| 200 | 16.5 | +15.6 | | | |

| | SAMPLE POINT | CLOCK TIME | VELOCITY HEAD ΔP in wg | ORIFICE METER ΔH in wg | GAS METER VOLUME FT³ | TEMPERATURES °F STACK | PROBE | IMPINGER | ORGANIC MODULE | OVEN | GAS METER IN | GAS METER OUT | PUMP VACUUM in Hg | √ΔP | Initial Leak Rate | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North Port | 1 in | 0 | .05 | .398 | 536.251 | 152 | 272 | | | | 90 | 89 | 5 | .224 | .016 at 15"Hg | 1235 |
| | 2 | 20 | .07 | .552 | 542.95 | 157 | 269 | | | | 89 | 89 | 6 | .265 | | |
| | 3 out | 40 | .07 | .555 | 550.72 | 156 | 272 | | | | 91 | 91 | 7 | .265 | .008 at 11"Hg | 1335 |
| | END | 60 | | | 558.701 | | | | | | | | | | | |
| | | | | | | | | Stop for thunderstorm | | | | | | | | |
| East Port | 1 in | 60 | .10 | .779 | 558.857 | 156 | 279 | | | | 81 | 81 | 8 | .316<br>~~.32~~ | .015 at 15"Hg | 1102 |
| | 2 | 80 | .10 | .783 | 568.27 | 153 | 272 | | | | 80 | 82 | 9 | ~~.32~~ .316 | | |
| | 3 out | 100 | .08 | .623 | 577.72 | 156 | 276 | | | | 81 | 81 | 8 | .283 | | |
| | END | 120 | | | 586.197 | | | | | | | | | | .012 at 11"Hg | 1702 |
| South Port | 1 in | 120 | .13 | 1.01 | 586.407 | 158 | 267 | | | | 80 | 80 | 9 | .361 | .008 at 15"Hg | 1730 |
| | 2 | 140 | .15 | 1.16 | 597.10 | 160 | 271 | | | | 79 | 79 | 11 | .387 | | |
| | 3 out | 160 | .13 | 1.00 | 608.49 | 159 | 270 | | | | 78 | 78 | 10 | .361 | | |
| | END | 180 | | | 619.180 | | | | | | | | | | .013 at 11"Hg | 1830 |
| West Port | 1 in | 150 | .10 | (.774)<br>.774 | 619.353 | 152 | 268 | | | | 75 | 73 | 8 | .316<br>~~.32~~ | .009 at 15"Hg | 1846 |
| | 2 | 200 | .09 | .703 | 628.74 | 146 | 271 | | | | 74 | 73 | 7 | .30 | | |
| | 3 out | 220 | .09 | .696 | 637.65 | 150 | 265 | | | | 72 | 72 | 8 | .30 | | 1946 |
| | END | 240 | | | 646.518 | | | | | | | | | | .008 at 11"Hg | |
| | | | | | | | | | | | 80.8 | 80.6 | | | | |
| | AVG/TOTAL | | | .753 | 109.728 | ~~155~~ | 154.5 | | | | | 80.7 | | .31 | .308 | |

ΔH = 8.869 7.5/7.5 ΔP

Form EED 021 1-79

PCB # 3
10/18/79

## PARTICULATE CALCULATIONS

1. Volume of dry gas sampled at standard conditions, 68° F, 29.92 inch Hg (scf)

$$Vm_{std} \quad 17.64\,\frac{Vm}{\alpha}\left(\frac{P_b + \frac{\Delta H}{13.6}}{T_{m,avg} + 460}\right) = 101.787 \qquad \alpha = 1.007$$

$$\text{or} \quad Vm_{stack} = \left(\frac{Vm}{\alpha} + Vw_{std}\right)\left(\frac{T_{s,avg} + 460}{T_{m,avg} + 460}\right)\left(\frac{P_m}{P_s}\right) \quad \text{(acf at stack conditions)}$$

=

2. Stack gas moisture condensed at standard conditions (scf)

$Vw_{std} = 0.04707\ Vl_c$ $\qquad Vl_c = 900 + 30.9$

= 43.817

3. Stack gas proportion of water vapor, by volume

$$B_{wo} = \frac{Vw_{std}}{Vw_{std} + Vm_{std}}$$

= 0.301

4. Stack gas dry molecular weight (lb/lb-mole)

$MW_d$ = 0.44 (%~~$CO_2$) +~~ 0.32 (%$O_2$) + 0.28 (%$N_2$ + %CO)

= 29.10

5. Stack gas molecular weight (lb/lb-mole)

$MW_s = MW_d\ (1 - B_{wo}) + 18\ (B_{wo})$

= 25.75

6. Pressure stack, in. Hg

$$P_s = P_b + \frac{P_{st}}{13.6}$$

= 29.47

7. Stack gas velocity at stack conditions (ft/sec)

$$V_s = 85.49\,(C_p)\,\left(\sqrt{\Delta P}\right)_{avg}\sqrt{\frac{T_{s,avg} + 460}{P_s\, MW_s}}$$

Cp = 0.67

= 15.9

8. Stack gas volume at standard conditions (scfm)

$$Q_s = 60\,(1 - B_{wo})\,Vs_{avg}\,A_s\left(\frac{528}{T_{s,avg} + 460}\right)\left(\frac{P_s}{29.92}\right) =$$ 44066

or $Q_a = 60\,Vs_{avg}\,A_s$ (acfm) =

9. Test percent isokinetic

$$\%I = \frac{17.33\,(T_{s,avg} + 460)\,\left[0.04707\,(W_{lc}) + Vm_{std}\right]}{\theta\, V_s\, P_s\, D_n^2}$$

=

10. Particulate matter concentration, gr/scf

$$C_s = 15.432\,\frac{M_p}{Vm_{std}} =$$

or $C_a = 15.432\,\dfrac{M_p}{Vm_{stack}}$ (gr/acf) =

11. Emission rate of particulate matter, lb/hr

$$ER = 0.00857\,(Q_s)\,C_s$$

=

12. Percent excess air at sampling point

$$\%\,EA = \frac{100\,[\%O_2 - 0.5\,(\%CO)]}{0.264\ \%N_2 - (\%O_2 - 0.5 \times \%CO)} =$$

13. Emission rate of particulate matter, lb/10⁶ Btu

$$E = 2.679 \times 10^{4}\left(\frac{M_p}{Vm_{std}}\right)F\left(\frac{20.9}{20.9 - \%O_2}\right)$$

# PARTICULATE TEST FIELD DATA SHEET

Plant ENSCO
Date 10-18-79
Test Location stack
Run Number 4 3rd PCB Burn
Stack Diameter inches 120"
Duct Dimensions in x in
Start Time 1050
Operator M. Clips

Barometric Pressure 29.49
Static Pressure -.22
Stack Pressure 29.47
Probe Number
Pitot Coefficient .167
Pitot Number #P-13
Meter Box Number 84 α=1.007
Orifice Coefficient .683

Nozzle Size & Number .371
Molecular Weight
BWO

FILTER DATA

| NUMBER | TARE | FINAL WT |
|---|---|---|
| | | |
| | | |
| | | |

| IMPINGER VOLUMES | | TIME | CO₂ | O₂ | CO |
|---|---|---|---|---|---|
| | | | 3.0 | 15.6 | |
| | | | | | |
| | 900 | | | | |
| | | | | | |
| 930.4 | | gain | | | |
| | | | | | |
| SILICA GEL | | | | | |
| 30.9 | | | | | |

| | SAMPLE POINT | CLOCK TIME | VELOCITY HEAD ΔP in wg | ORIFICE METER ΔH in wg | GAS METER VOLUME FT³ | TEMPERATURES °F | | | | | | | PUMP VACUUM in Hg | √ΔP | Initial/Leak Rate | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | STACK | PROBE | IMPINGER | ORGANIC MODULE | OVEN | GAS METER IN | GAS METER OUT | | | | |
| west port | 1 in | 0 | .08 | .628 | 646.627 | 153 | 277 | | | | 95 | 96 | 6 | .283 | .018 at 15"Hg | 1050 |
| | 2 | 20 | .09 | .700 | 654.95 | 159 | 272 | | | | 95 | 96 | 7 | .300 | | |
| | 3 out | 40 | .08 | .621 | 663.85 | 159 | 277 | | | | 94 | 95 | 7 | .283 | | |
| | END | 60 | | | 672.158 | | | | | | | | | | .012 at 11"Hg | 1150 |
| | | | | | | | | | | | | | | | | |
| south port | 1 in | 60 | .13 | 1.01 | 672.427 | 160 | 272 | | | | 96 | 96 | 10 | .361 | .016 at 15"Hg | 1208 |
| | 2 | 80 | .13 | 1.02 | 683.07 | 158 | 266 | | | | 97 | 97 | 10 | .361 | | |
| | 3 out | 100 | .11 | .852 | 693.70 | 159 | 277 | | | | 92 | 95 | 9 | .332 | | 1308 |
| | END | 120 | | | 703.543 | | | | | | | | | | .007 at 11"Hg | |
| | | | | | | | | | | | | | | | | |
| East port | 1 in | 120 | .12 | .914 | 703.710 | 166 | 272 | | | | 90 | 91 | 9 | .346 | .018 at 15"Hg | 1332 |
| | 2 | 140 | .13 | .995 | 713.74 | 160 | 277 | | | | 87 | 87.5 | 10 | .361 | | |
| | 3 out | 160 | .10 | .766 | 724.26 | 160 | 268 | | | | 87 | 89 | 11 | .316 | | 1432 |
| | END | 180 | | | 733.603 | | | | | | | | | | .013 at 11"Hg | |
| | | | | | | | | | | | | | | | | |
| North port | 1 in | 180 | .06 | .459 | 733.746 | 163 | 276 | | | | 89 | 90 | 6 | .245 | .015 at 15"Hg | 1450 |
| | 2 | 200 | .07 | .535 | 744.90 | 162 | 271 | | | | 87 | 90 | 7 | .265 | | |
| | 2 out | 220 | .06 | .460 | 748.63 | 159 | 278 | | | | 87 | 89 | 7 | .245 | | |
| | END | 240 | | | 755.860 | | | | | | | | | | .010 at 11"Hg | 1550 |
| | | | | .747 | 108.602 | 159.0 | | | | | 91.3 | 93.0 | | | | |
| | AVG/TOTAL | | | GHc | £.666 tm/ts ΔP | | | | | | 92.2 | 93 | | .308 | | |

Form EED [illegible]

PLANT Enaco OPERATOR Sert & Jamien

LOCATION

DATE 10-15-79

TIME

AMBIENT PRESSURE (IN. HG.) 27.81
AMBIENT TEMPERATURE (°F)
SAMPLING POINT west duct

TEST NUMBER #1 Baseline

NO$_x$ SAMPLING DATA

Barom = 29.72

| Time | Flask Number | Flask Volume (ml.) | Initial Conditions | | Final Conditions | |
|---|---|---|---|---|---|---|
| | | | Flask Vacuum (in. Hg.) | Flask Temp (°F) | Flask Vacuum (in. Hg.) | Flask Temp (°F) |
| 1430 | 19 | 2090 | 28.6 | 80°F | 1.4 | 69 |
| 1500<br>~~[illegible]~~ | 17 | 2077 | 28.0 | 82°F | .8 | 69 |
| 1615 | 11 | 2030 | 28.2 | 82F | .9 | 69 |
| 1721 | 15 | 2035 | 28.3 | 80 | .8 | 69 |

PLANT Ensco OPERATOR

LOCATION

DATE 10-16-79

TIME

AMBIENT PRESSURE (IN. HG.) 29.72
AMBIENT TEMPERATURE (°F)
SAMPLING POINT South Duct #3 point

TEST NUMBER 2

NO$_x$ SAMPLING DATA

Barom. = 29.78

| Time | Flask Number | Flask Volume (ml.) | Initial Conditions | | Final Conditions | |
|---|---|---|---|---|---|---|
| | | | Flask Vacuum (in. Hg.) | Flask Temp (°F) | Flask Vacuum (in. Hg.) | Flask Temp (°F) |
| 1540 | #19 | 2090 | 28.4 | 90 | 1.4 | 72 |
| 1615 | #40 | 2044 | 28.5 | 86 | * — | 72 |
| 1715 | #11 | 2030 | 27.6 | 88 | 1.24 | 72 |
| 1810 | #2 | 2036 | 28.3 | 87 | 1.32 | 72 |

* Tee became loose during final shaking (after allowing to sit for 16 hrs)

* assum 1.2

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PLANT Tnaco
OPERATOR farmer
LOCATION
DATE 10-17-77
TIME
AMBIENT PRESSURE (IN. HG.) 29.78
AMBIENT TEMPERATURE (°F)
SAMPLING POINT
TEST NUMBER 3

## $NO_x$ SAMPLING DATA

Barom. = 29.49

| | Time | Flask Number | Flask Volume (ml.) | Initial Conditions | | Final Conditions | |
|---|---|---|---|---|---|---|---|
| | | | | Flask Vacuum (in. Hg.) | Flask Temp (°F) | Flask Vacuum (in. Hg.) | Flask Temp (°F) |
| South of 3 | 1235 | #15 | 2035 | 28.7 | 83 | .9 | 69 |
| North of 3 | 1740 | #17 | 2079 | 28.4 | 85 | 1.4 | 69° |
| north of 3 | 1830 | #4 | 2044 | 28.6 | 83 | 1.0 | 69° |
| ↓ | 1920 | #3 | 2079 | 28.2 | 78 | .6 | 65° |

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PLANT Emco OPERATOR Jarmon & Best

LOCATION

DATE 10-18-79

TIME

AMBIENT PRESSURE (IN. HG.) 29.49
AMBIENT TEMPERATURE (°F)
SAMPLING POINT

TEST NUMBER 4

### NO$_x$ SAMPLING DATA

Barom. = 30.05

| | Time | Flask Number | Flask Volume (ml.) | Initial Conditions | | Final Conditions | |
|---|---|---|---|---|---|---|---|
| | | | | Flask Vacuum (in. Hg.) | Flask Temp (°F) | Flask Vacuum (in. Hg.) | Flask Temp (°F) |
| East #3 | 1320 | #2 | 2036 | 27.9 | 84 | 1.5 | 69 |
| West #3 | 1408 | #11 | 2030 | 28.1 | 89 | .13 | 69 |
| ↓ | 1440 | #19 | 2090 | 28.1 | 87 | .12 | 69 |
| | 1540 | #3 | 2079 | 28.1 | 87 | 1.45 | 69 |

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## ANALYTICAL REPORT FORM

| SAMPLE NUMBER | SAMPLE I. D. | SPECIES | RESULT less than 1. |
|---|---|---|---|
| 79-3485 | DAY 1 FLASK 11 | | <1.5 |
| 79-3486* | DAY 1 FLASK 15 | | 51.8 |
| 79-3487 | DAY 1 FLASK 17 | | 71.0 |
| 79-3488 | DAY 1 FLASK 19 | | 26.7 |
| 79-3489 | DAY 2 FLASK 2 | | 5.23 |
| 79-3490* | DAY 2 FLASK 4 | | 78.4 |
| 79-3491 | DAY 2 FLASK 11 | | 6.3 |
| 79-3492* | DAY 2 FLASK 19 | | 72.2 |
| 79-3493 | DAY 3 FLASK 3 | | 42.4 |
| 79 3493 DUPLICATE | DAY 3 FLASK 3 | | 37.8 |
| | | | 40.1 = MEAN |
| 79-3494 | DAY 3 FLASK 4 | | 60.4 |
| 79-3495 | DAY 3 FLASK 15 | | 9.4 |
| 79-3496 | DAY 3 FLASK 17 | | 37.1 |
| 79-3497 | DAY 4 FLASK 2 | | 19.6 |
| 79-3498 | DAY 4 FLASK 3 | | 27.2 |
| 79-3499 | DAY 4 FLASK 11 | | 90.6 |
| 79-3500 | DAY 4 FLASK 17 | | 18.1 |

% ERROR = 11.5%

SPIKE ANALYSIS
SAMPLE 79-3499 DAY 4 FLASK 11

$\frac{\text{FOUND}}{\text{ACTUAL}} = \% \; \frac{F:.192}{A:.181} = 106\%$ RECOVERY

$\frac{42.4 - 37.8}{40.1} \times 100 = \%$ ERROR

SAMPLES STARRED HAD BROWN PPT FORM DURING EVAPORATION.

Analyst John McLaurin
Approved Beth Heffernan
Date 12-7-79

Baseline 10/15/79
Flask 19

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64 \, (V_f - 25)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64 \, (2090 - 25)\left(\frac{28.32}{529} - \frac{1.21}{540}\right)$$

$$= 1868.5$$

$$C = 6.243 \times 10^{-5}\left(\frac{m}{V_{sc}}\right)$$

$$= 6.243 \times 10^{-5}\left(\frac{26.7}{1868.5}\right)$$

$$= 8.92 \times 10^{-7}$$

$$ER = 60 \, Q_s \, C$$

$$= 60 \, (46{,}358)(8.92 \times 10^{-7})$$

$$= 2.5 \text{ lb/hr}$$

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Baseline 10/15/80
Flask 17

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \; (V_f - 25) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \; (2079 - 25) \left( \frac{28.92}{529} - \frac{1.81}{542} \right)$$

$$= 1859.8$$

$$C = 6.243 \times 10^{-5} \left( \frac{m}{V_{sc}} \right)$$

$$= 6.243 \times 10^{-5} \left( \frac{71.0}{1859.8} \right)$$

$$= 2.38 \times 10^{-6}$$

$$\mathcal{E}R = 60 \; Q_s \; C$$

$$= 60 \; (46{,}358 \;)(2.38 \times 10^{-6})$$

$$= 6.6 \text{ lb/hr}$$

Baseline 10/15/79
Flask 11

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (V_f - 25)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (2030-25)\left(\frac{28.82}{529} - \frac{1.61}{542}\right)$$

$$= 1821.8$$

$$C = 6.243\times10^{-5}\left(\frac{m}{V_{sc}}\right)$$

$$= 6.243\times10^{-5}\left(\frac{1.5}{1821.8}\right)$$

$$= 5.14\times10^{-8}$$

$$ER = 60\ Q_s\ C$$

$$= 60\ (46{,}358)(5.14\times10^{-8})$$

$$= 0.1\ \text{lb/hr}$$

Baseline 10/15/79
Flask 15

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (V_f - 25)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (2035 - 25)\left(\frac{28.92}{529} - \frac{1.51}{540.}\right)$$

$$= 1839.2$$

$$C = 6.243 \times 10^{-5}\left(\frac{m}{V_{sc}}\right)$$

$$= 6.243 \times 10^{-5}\left(\frac{51.8}{1839.2}\right)$$

$$= 1.75 \times 10^{-6}$$

$$ER = 60\ Q_s\ C$$

$$= 60\ (46,358)(1.75 \times 10^{-6})$$

$$= 4.9\ \text{lb/hr}$$

PCB #1 10/16/79
Flask 19

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (V_f - 25)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (2090 - 25)\left(\frac{28.38}{532} - \frac{1.32}{550}\right)$$

$$= 1855.7$$

$$C = 6.243 \times 10^{-5}\left(\frac{m}{V_{sc}}\right)$$

$$= 6.243 \times 10^{-5}\left(\frac{72.2}{1855.7}\right)$$

$$= 2.42 \times 10^{-6}$$

$$ER = 60\ Q_s\ C$$

$$= 60\ (47,883)(2.42 \times 10^{-6})$$

$$= 6.4\ \text{lb/hr}$$

PCB #1 10/16/79
Flask 4

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \, (V_f - 25) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \, (2044 - 25) \left( \frac{28.58^*}{532} - \frac{1.22}{546} \right)$$

$$= 1833.7$$

* assumed

$$C = 6.243 \times 10^{-5} \left( \frac{m}{V_{sc}} \right)$$

$$= 6.243 \times 10^{-5} \left( \frac{78.4}{1833.7} \right)$$

$$= 2.66 \times 10^{-6}$$

$$ER = 60 \, Q_s \, C$$

$$= 60 \, (43{,}883) (2.66 \times 10^{-6})$$

$$= 7.0 \text{ lb/hr}$$

PCB #1 10/16/79
Flask 11

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (V_f - 25)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (2030 - 25)\left(\frac{28.54}{532} - \frac{2.12}{548}\right)$$

$$= 1760.5$$

$$C = 6.243\times10^{-5}\left(\frac{m}{V_{sc}}\right)$$

$$= 6.243\times10^{-5}\left(\frac{6.3}{1760.5}\right)$$

$$= 2.23\times10^{-7}$$

$$ER = 60\ Q_s\ C$$

$$= 60\ (43{,}883)(2.23\times10^{-7})$$

$$= 0.6\ \text{lb/hr}$$

PCB #1 10/16/79
Flask 2

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (V_f - 25)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (2036 - 25)\left(\frac{28.46}{532} - \frac{1.42}{547}\right)$$

$$= 1805.6$$

$$C = 6.243\times10^{-5}\left(\frac{m}{V_{sc}}\right)$$

$$= 6.243\times10^{-5}\left(\frac{5.23}{1805.6}\right)$$

$$= 1.80\times10^{-7}$$

$$ER = 60\ Q_s\ C$$

$$= 60\ (43{,}883)(1.80\times10^{-7})$$

$$= 0.5\ \text{lb/hr}$$

PCB #2 10/17/79
Flask 15

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \, (V_f - 25) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \, (2035 - 25) \left( \frac{28.59}{529} - \frac{1.08}{543} \right)$$

$$= 1845.7$$

$$C = 6.243 \times 10^{-5} \left( \frac{m}{V_{sc}} \right)$$

$$= 6.243 \times 10^{-5} \left( \frac{9.4}{1845.7} \right)$$

$$= 3.17 \times 10^{-7}$$

$$ER = 60 \, Q_s \, C$$

$$= 60 \, (43{,}700)(3.17 \times 10^{-7})$$

$$= 0.8 \text{ lb/hr}$$

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PCB#2 10/17/79
Flask 17

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (V_f - 25)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (2079 - 25)\left(\frac{28.09}{529} - \frac{1.38}{545}\right)$$

$$= 1832.2$$

$$C = 6.243\times10^{-5}\left(\frac{m}{V_{sc}}\right)$$

$$= 6.243\times10^{-5}\left(\frac{37.1}{1832.2}\right)$$

$$= 1.26\times10^{-6}$$

$$ER = 60\ Q_s\ C$$

$$= 60\ (43{,}700)(1.26\times10^{-6})$$

$$= 3.3\ \text{lb/hr}$$

PCB # 2 10/17/79
Flask 4

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \, (V_f - 25) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \, (2044 - 25) \left( \frac{28.49}{529} - \frac{1.18}{543} \right)$$

$$= 1840.7$$

$$C = 6.243 \times 10^{-5} \left( \frac{m}{V_{sc}} \right)$$

$$= 6.243 \times 10^{-5} \left( \frac{60.4}{1840.7} \right)$$

$$= 2.04 \times 10^{-6}$$

$$ER = 60 \, Q_s \, C$$

$$= 60 \, (43{,}700)(2.04 \times 10^{-6})$$

$$= 5.4 \text{ lb/hr}$$

PCB #2 10/17/79
Flask 3

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (V_f - 25)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (2079 - 25)\left(\frac{28.89}{529} - \frac{1.58}{538}\right)$$

$$= 1872.3$$

$$C = 6.243 \times 10^{-5}\left(\frac{m}{V_{sc}}\right)$$

$$= 6.243 \times 10^{-5}\left(\frac{40.1}{1872.3}\right)$$

$$= 1.33 \times 10^{-6}$$

$$ER = 60\ Q_s\ C$$

$$= 60\ (43{,}700)(1.33 \times 10^{-6})$$

$$= 3.5\ \text{lb/hr}$$

PCB #3 10/18/79
Flask 2

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \, (V_f - 25) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \, (2036 - 25) \left( \frac{28.55}{529} - \frac{1.59}{544} \right)$$

$$= 1810.8$$

$$C = 6.243 \times 10^{-5} \left( \frac{m}{V_{sc}} \right)$$

$$= 6.243 \times 10^{-5} \left( \frac{19.6}{1810.8} \right)$$

$$= 6.75 \times 10^{-7}$$

$$ER = 60 \, Q_s \, C$$

$$= 60 \, (43{,}208)(6.75 \times 10^{-7})$$

$$= 1.8 \text{ lb/hr}$$

149

PCB #3 10/18/79
Flask 11

# NO$_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64 \, (V_f - 25)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64 \, (2030-25)\left(\frac{29.92}{529} - \frac{1.39}{549}\right)$$

$$= 1910.8$$

$$C = 6.243 \times 10^{-5}\left(\frac{m}{V_{sc}}\right)$$

$$= 6.243 \times 10^{-5}\left(\frac{90.6}{1910.8}\right)$$

$$= 2.96 \times 10^{-6}$$

$$ER = 60 \, Q_s \, C$$

$$= 60 \, (43{,}208)(2.96 \times 10^{-6})$$

$$= 7.7 \text{ lb/hr}$$

150

PCB #3 10/18/79
Flask 19

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (V_f - 25)\left(\frac{P_f}{T_f} - \frac{P_i}{T_i}\right)$$

$$= 17.64\ (2090 - 25)\left(\frac{29.93}{529} - \frac{1.39}{547}\right)$$

$$= 1968.3$$

$$C = 6.243 \times 10^{-5}\left(\frac{m}{V_{sc}}\right)$$

$$= 6.243 \times 10^{-5}\left(\frac{18.1}{1968.3}\right)$$

$$= 5.74 \times 10^{-7}$$

$$ER = 60\ Q_s\ C$$

$$= 60\ (43{,}208)(5.74 \times 10^{-7})$$

$$= 1.5\ \text{lb/hr}$$

PCB #3 10/18/79
Flask 3

# $NO_x$ Calculations

$$V_{sc} = \frac{T_{std}}{P_{std}} (V_f - V_a) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \, (V_f - 25) \left( \frac{P_f}{T_f} - \frac{P_i}{T_i} \right)$$

$$= 17.64 \, (2079 - 25) \left( \frac{28.60}{529} - \frac{1.39}{547} \right)$$

$$= 1868.8$$

$$C = 6.243 \times 10^{-5} \left( \frac{m}{V_{sc}} \right)$$

$$= 6.243 \times 10^{-5} \left( \frac{27.2}{1868.8} \right)$$

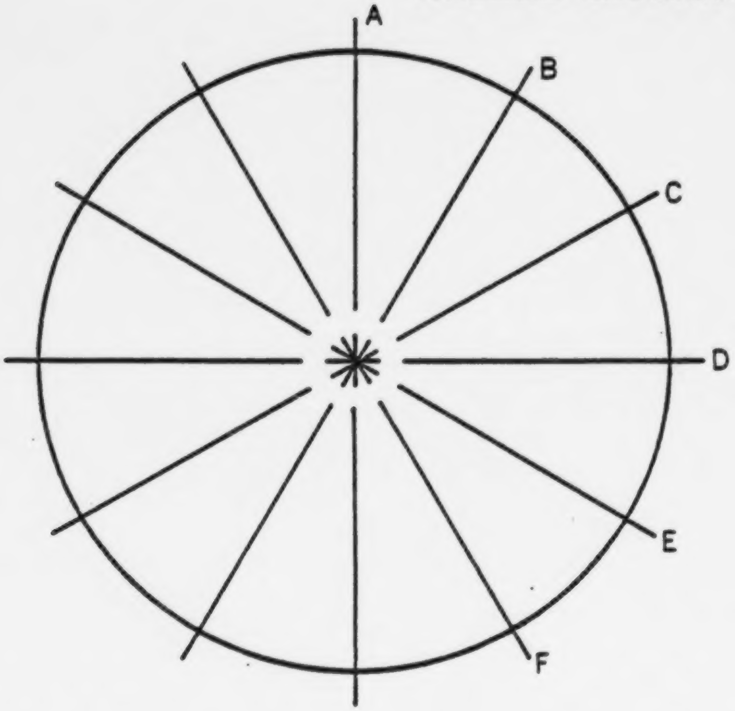
$$= 9.09 \times 10^{-7}$$

$$ER = 60 \, Q_s \, C$$

$$= 60 \, (43{,}208)(9.09 \times 10^{-7})$$

$$= 2.4 \text{ lb/hr}$$

# NOZZLE MEASUREMENT



DIAMETER
DIMENSION
A .369
B .370
C .368
D .371
E .371
F .370

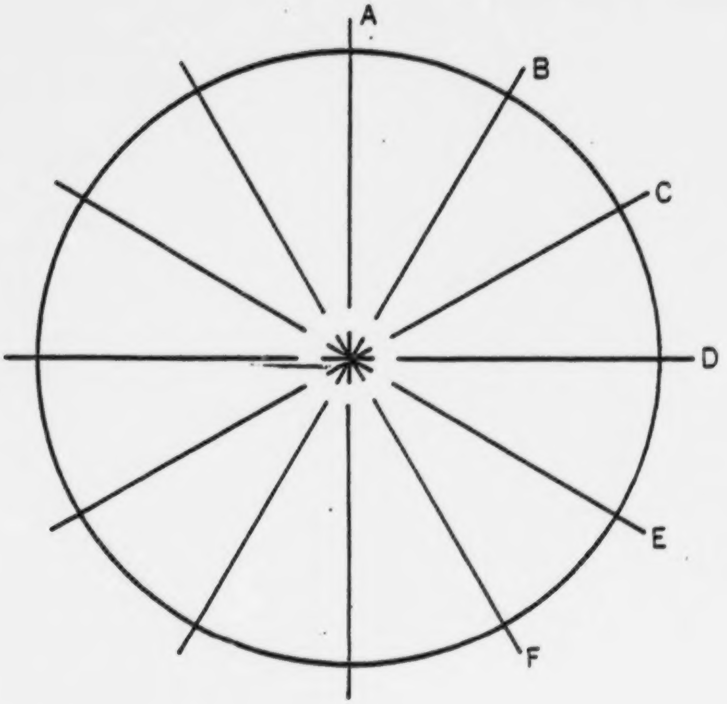
AVG. .370

NOZZLE SERIAL
P-6

DATE
10-31-79

RECORDED BY
M. Chilps

## NOZZLE MEASUREMENT



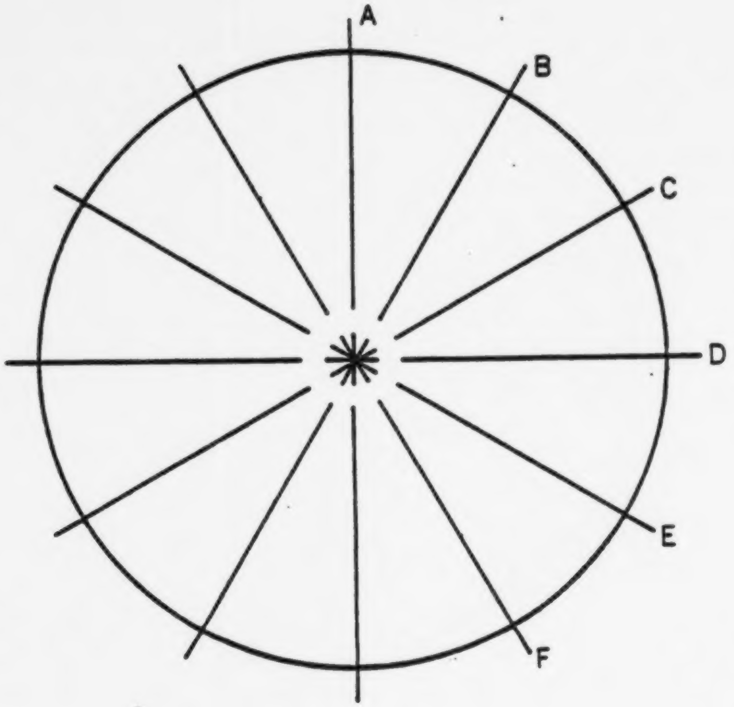
DIAMETER
DIMENSION
A .498
B .500
C
D .495
E
F .498

AVG. .4978
NOZZLE SERIAL

DATE 1/8/79

RECORDED BY
Kaufmann

# NOZZLE MEASUREMENT



DIAMETER DIMENSION
A .406
B .405
C
D .406
E
F .404

AVG. .4053
NOZZLE SERIAL

DATE 1/9/79

RECORDED BY

155

Date 4/18/79
Time 1500
Barometric Pressure 30.26
Ambient Temperature 70°F

Orifice Meter 520-084
Orifice Magnehelic 80615BW28
Primary Calibration Meter 259453
Control Module 520 - 084

Operators Rautmann
Wet Bulb Temperature

## METER CALIBRATION DATA

Orfice Plate 084

| Orifice Manometer $\Delta H_{ref}$ (in.wg.) | Orifice Magnehelic $\Delta H_0$ (in.wg.) | Primary Meter $\Delta H_p$ (in.wg.) | Dry Test Meter $P_{dg}$ (in. wg.) | Gas Volume Primary Meter $V_p$ (ft.³) | Gas Volume Dry Test Meter $V_d$ (ft.³) | Temperature Primary Meter Inlet, $T_{pi}$ (°F) | Temperature Primary Meter Outlet, $T_{po}$ (°F) | Temperature Primary Meter Avg., $T_{pa}$ (°F) | Temperature Dry Test Meter Inlet, $T_{di}$ (°F) | Temperature Dry Test Meter Outlet, $T_{do}$ (°F) | Temperature Dry Test Meter Avg., $T_{da}$ (°F) | Time t (min.) | α | $K_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.77 | 0.8 | | | 191.702<br>208.476 | 586.812<br>603.572 | 66<br>66 | 66<br>66 | 66 | 67<br>68 | 67<br>70 | 68 | 35 | .997 | .690 |
| | | | | 16.774 | 16.760 | | | | | | | | | |
| 1.76 | 1.8 | | | 208.476<br>228.467 | 603.572<br>623.706 | 66<br>67 | 66<br>66 | 66 | 69<br>70 | 70<br>72 | 70 | 28 | 1.004 | .684 |
| | | | | 19.991 | 20.134 | | | | | | | | | |
| 2.75 | 2.8 | | | 228.467<br>249.748 | 623.706<br>645.245 | 67<br>68 | 66<br>66 | 67 | 69<br>70 | 72<br>72 | 71 | 24 | 1.011 | .681 |
| | | | | 21.281 | 21,539 | | | | | | | | | |
| 3.78 | 3.8 | | | 249.748<br>269.229 | 645.245<br>664.993 | 68<br>71 | 66<br>67 | 68 | 70<br>72 | 72<br>74 | 72 | 19 | 1.015 | .675 |
| | | | | 19.481 | 19.748 | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

$K_0$ 0.683
α 1.007

| Average | |
|---|---|
| α | $K_0$ |
| | |

156

Date 7-25-79
7-27-79

Time 10:15

Barometric Pressure 29.88

Ambient Temperature 30.02
75$^0$, 72$^0$

Orifice Meter 570 085

Orifice Magnehelic 806291BW89

Primary Calibration Meter 259453

Control Module 570 - 085

Operators Seegmiller

Wet Bulb Temperature

METER CALIBRATION DATA Orifice Plate 085

| Orifice Manometer $\Delta H_{ref}$ (in.wg.) | Orifice Magnehelic $\Delta H_0$ (in.wg.) | Primary Meter $\Delta H_p$ (in.wg.) | Dry Test Meter $P_{dg}$ (in. wg.) | Gas Volume Primary Meter $V_p$ (ft.$^3$) | Gas Volume Dry Test Meter $V_d$ (ft.$^3$) | Temperature: Primary Meter: Inlet, $T_{pi}$ (°F) | Outlet, $T_{po}$ (°F) | Avg., $T_{pa}$ (°F) | Dry Test Meter: Inlet, $T_{di}$ (°F) | Outlet, $T_{do}$ (°F) | Avg., $T_{da}$ (°F) | Time t (min.) | α | $K_0$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.80 | 0.8 | | | 249.622<br>239.562 | 108.450<br>098.450 | 76<br>77 | 77<br>77 | 76.75 | 75<br>75 | 75<br>75 | 75 | 19.9 | 1.019 | .719 |
| | | | | 10.060 | 10.000 | | | | | | | | | |
| 1.80 | 1.8 | | | 259.622<br>249.622 | 118.450<br>108.450 | 76<br>78 | 76<br>77 | 76.75 | 76<br>76 | 77<br>76 | 76.25 | 13.6 | 1.016 | .699 |
| | | | | 10.040 | 10.000 | | | | | | | | | |
| 2.82 | 2.8 | | | 269.742<br>259.662 | 128.450<br>118.450 | 79<br>81 | 77<br>77 | 78.5 | 76<br>76 | 76<br>76 | 76 | 11.0 | 1.032 | .696 |
| | | | | 10.080 | 10.000 | | | | | | | | | |
| 3.84 | 3.8 | | | 279.778<br>269.742 | 138.450<br>128.450 | 75<br>76 | 76<br>76 | 75.75 | 75<br>75 | 75<br>75 | 75 | 9.5 | 1.016 | .689 |
| | | | | 10.036 | 10.000 | | | | | | | | | |

α 1.019
$K_0$ 0.701

| Average | |
|---|---|
| α | $K_0$ |

DATE 8-17-79
TIME 0745
BAROMETRIC PRESSURE 30.06
AMBIENT TEMP $69^{0}F$

TEST PITOT TUBE P-13
STANDARD PITOT TUBE UNITED SENSOR
TEST SECTION LOCATION WINDTUNNEL
OPERATORS JARMAN

NOZZLE SIZE
NOZZLE-PITOT SPACING
PITOT-TC SPACING

## PITOT TUBE CALIBRATION DATA

| Test Pitot Tube ΔP (in. wg.) | | Standard Pitot Tube | $C_p$ | | Test Section Velocity (fps). |
|---|---|---|---|---|---|
| Upper Leg | Lower Leg | ΔP (in. wg.) | Upper | Lower | |
| 0.04 | 0.04 | 0.01 | $0.99 \left(\frac{.01}{.04}\right)^{.5} = 0.50$ | 0.50 | |
| 0.07 | 0.07 | 0.03 | $0.99 \left(\frac{.03}{.07}\right)^{.5} = 0.65$ | 0.65 | |
| 0.08 | 0.09 | 0.04 | $0.99 \left(\frac{.04}{.08}\right)^{.5} = 0.70$ | $0.99 \left(\frac{.04}{.09}\right)^{.5} = 0.66$ | |
| 0.13 | 0.13 | 0.07 | $0.99 \left(\frac{.07}{.13}\right)^{.5} = 0.73$ | 0.73 | |
| 0.16 | 0.17 | 0.1 | $0.99 \left(\frac{.10}{.16}\right)^{.5} = 0.78$ | $0.99 \left(\frac{.10}{.17}\right)^{.5} = 0.76$ | |
| | | | Average 0.67 | 0.66 | |
| | | | | | |
| | | | | | |
| | | | | | |

Average $C_{p,\ upper} = 0.67$

Average $C_{p,\ lower} = 0.66$

158

DATE 8-17-80
TIME 0830
BAROMETRIC PRESSURE 30.06
AMBIENT TEMP 69$^{0}$F

TEST PITOT TUBE P-12
STANDARD PITOT TUBE UNITED SENSOR
TEST SECTION LOCATION WINDTUNNEL
OPERATORS JARMAN

NOZZLE SIZE
NOZZLE-PITOT SPACING
PITOT-TC SPACING

## PITOT TUBE CALIBRATION DATA

| Test Pitot Tube ΔP (in. wg.) | | Standard Pitot Tube ΔP (in. wg.) | $C_p$ | | Test Section Velocity (fps) |
|---|---|---|---|---|---|
| Upper Leg | Lower Leg | | Upper | Lower | |
| 0.04 | 0.05 | 0.02 | $0.99\left(\frac{.02}{.04}\right)^{.5} = 0.70$ | $0.99\left(\frac{.02}{.05}\right)^{.5} = 0.63$ | |
| 0.07 | 0.07 | 0.03 | $0.99\left(\frac{.03}{.07}\right)^{.5} = 0.65$ | 0.65 | |
| 0.1 | 0.1 | 0.05 | $0.99\left(\frac{.05}{.10}\right)^{.5} = 0.70$ | 0.70 | |
| 0.13 | 0.14 | 0.08 | $0.99\left(\frac{.08}{.13}\right)^{.5} = 0.78$ | $0.99\left(\frac{.08}{.14}\right)^{.5} = 0.75$ | |
| | | | Average 0.71 | 0.68 | |
| | | | | | |
| | | | | | |
| | | | | | |

Average $C_{p,\ upper}$ = 0.71

Average $C_{p,\ lower}$ = 0.68

## EPRI FP-1207 Volume 4

Below are five index cards that allow for filing according to the four cross-references in addition to the title of the report. A brief abstract describing the major subject area covered in the report is included on each card. For information regarding index card subscriptions to past and future EPRI publications contact the Research Reports Center, P.O. Box 50490, Palo Alto, California 94303. Telephone (415) 965-4081.

EPRI

**EPRI FP-1207**
**Volume 4**
**RP1263-2**
**Final Report**
**September 1980**

### Disposal of Polychlorinated Biphenyls (PCBs) and PCB-Contaminated Materials Volume 4: Test Incineration of Electrical Capacitors Containing PCBs

Contractor: Acurex Corporation

Volume 4 presents a study of a trial burn conducted to determine whether liquid polychlorinated biphenyls (PCBs) and shredded electronic capacitors can be incinerated according to Environmental Protection Agency regulations. The report contains (1) a brief overview of published literature on PCB burning, (2) a description of the Energy Systems Company facility, (3) a discussion of sampling and analysis procedures, (4) a summary of results obtained from the trial burn, and (5) a collection of raw data and sample calculations used to obtain the results.

EPRI Project Manager: R. Y. Komai

Cross-references:
1. EPRI FP-1207, Volume 4 2. RP1263-2 3. Water Quality Control and Heat Rejection Program 4. PCB-Contaminated Materials

ELECTRIC POWER RESEARCH INSTITUTE
Post Office Box 10412, Palo Alto, CA 94303 415-855-2000

EPRI FP-1207, VOLUME 4

EPRI

EPRI FP-1207
Volume 4
RP1263-2
Final Report
September 1980

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RP1263-2

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WATER QUALITY CONTROL AND HEAT REJECTION PROGRAM

EPRI

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Volume 4
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EPRI Project Manager: R. Y. Komai

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PCB-CONTAMINATED MATERIALS

EPRI

EPRI FP-1207
Volume 4
RP1263-2
Final Report
September 1980

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# Division 2

161

# THE PCB INCINERATION TEST
# MADE BY ROLLINS ENVIRONMENTAL SERVICES (TX)
# AT DEER PARK, TEXAS

NOVEMBER 12-16, 1979

A Report to the United States
Environmental Protection Agency, Region 6
Dallas, Texas

## RECIPIENTS OF COPIES OF THIS REPORT

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| RES (TX), Inc.<br>Box 609<br>Deer Park, TX 77536 | Original retained on file |

## Observers and Participants in PCB Incineration Test

November 12-15, 1979

U.S. EPA, Region 6
    Charles Gazdo
    Frank Hall
    Jim Sales
    Phil Schwindt

Texas Department of Water Resources
    Clarence Johnson

Texas Air Control Board
    G. McArthur
    Son Vo

Harris County Pollution Control Department
    G. M. Combs

TRW (EPA contractor)
    R. J. Johnson

City of Houston, Board of Air Quality Control
    Virginia Knab

Rollins Environmental Services

| | |
|---|---|
| R. P. Ellis | Wilmington, DE |
| RES(TX), Inc. | Operating Personnel |

Environment One Corporation
    Mike Kawahata
    Stack Sampling team

164.

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Report on Stack Gas Sampling and Analyses

## SUMMARY

A liquid waste containing 35 wt% PCB's was incinerated at Rollins Environmental Services (TX), Inc in Deer Park, Texas with a destruction efficiency >99.99997% and a combustion efficiency of 99.993%. A chloride balance showed that the scrubber was 98.4% efficient. The minimum incineration control temperature was 1146° C; and, the dwell time was calculated as 2.68 seconds.

Continuous monitoring of the flue gas showed the carbon monoxide concentration was <12 ppm and the oxygen concentration was >7%.

All automatic cut-off systems were operational during the incineration.

No PCB's, chlorinated dibenzofurans nor, chlorocarbons were detected in the flue gas. Water quality of Outfall 001 water was well below the specifications in TDWR Permit No 01429 and NPDES Permit No TX0005941 and contained no detectable PCB's.

## INTRODUCTION

In accord with CFR 40-761.40 RES (TX), Inc submitted to the Regional Administrator of U.S. EPA Region 6 an application for permission to incinerate liquid and solid (mainly capacitors) wastes containing PCB's at its Deer Park, Texas facility. In this application of April 5, 1978 RES (TX), Inc. asked, in the main, for relief from a trial incineration of PCB's because it had incinerated PCB's under subcontract to TRW which was operating as a U.S. EPA contractor.(1) When this relief was denied RES (TX), Inc submitted a revised application for liquid and solid PCB wastes on February 28, 1979: having submitted on February 14, 1979 a proposed plan for conducting and monitoring a trial incineration.

Subsequently, RES (TX), Inc encountered mechanical problems with the capacitor shredding machinery and elected to temporarily delay that part of the test incineration relating to solid wastes. In accord with this decision RES (TX), Inc submitted a second revised application on October 4, 1979 which pertained solely to the incineration of liquid PCB's.

After several communications amongst Region 6, RES (TX), Inc, and, RES (TX), Inc sub-contractors personnel, agreement to the proposed plan was reached and the incineration test was made during the week of November 11, 1979 at Deer Park, Texas.

As sub-contractors to RES (TX), Inc, Environment One(2) took the stack gas samples and analyzed them. NUS (3) analyzed the water samples for PCB's and the incinerator feed streams for metals content. The elemental composition of the incinerator feed streams was determined by SPL.(4) Certain other parameters, such as pH and Total Organic Carbon (TOC), of the water samples were measured in the RES (TX), Inc laboratory.

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(1) Destroying Chemical Wastes in Commercial Scale Incinerators-Facility Report No.6 Rollins Environmental Services, Inc., Ackerman, D.G., et al, U.S. Environmental Protection Agency, Office of Solid Waste Management Programs, Washington, D.C. 20460, June 1977.

(2) Environment One Corporation, 2773 Balltown Road, Schenectady, NY 12309.

## THE PCB TEST EQUIPMENT

These incineration tests were made at RES (TX), Inc plant site at 2027 Battleground Road, Deer Park, Texas (Fig 1).(5) The incinerator complex consists of a Bartlett-Snow rotary kiln and a modified Loddby liquid burner both discharging into a common afterburner chamber. Flue gas from the afterburner goes to a Flexi-Venturi scrubber (dilute lime slurry) and a bubble tray absorber (water) to remove particulates and acidic gases. The scrubbed flue gas leaves through a stack. This complex is shown in Figures 2,3,4,5, and 6.(6)

The temperatures throughout the complex were measured with certified, calibrated thermocouples (Figs 3 & 4) and the results continuously recorded (Figs 13 & 14). A minimum temperature profile was maintained by using the hot duct thermocouple (Fig 4) to activate the automatic feed cut-off (Figs 7 & 8) whenever that temperature fell below 1113°C.

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(3) NUS Corporation, 900 Gemini Avenue, Houston, TX 77058.

(4) Southern Petroleum Laboratories, Inc , P.O. Box 20807, Houston, TX 77025.

(5) A U.S. Dept of Interior, Geologic Survey topographic map of the La Porte, Texas quadrangle and an aerial map of RES(TX), Inc plant site are shown in Appendices 1 and 2 to Rollins Environmental Services Report and Application for Approval of Proposed PCB Landfill submitted to U.S. EPA Region 6 on December 1, 1978.

(6) A detailed discussion of the principal parts of this complex is given in Application for Approval to Incinerate Polychlorinated Biphenyl Compounds and Wastes at Rollins Environmental Services(TX) Inc, Deer Park, Texas, submitted to U.S. EPA Region 6, February 28, 1979.

The pressure drop across the Venturi throat was continuously measured and recorded (Fig 17) to show $\Delta p$ was maintained above 40 inches (water).

A Beckman Model 865 NDIR continuous analyzer and controller for carbon monoxide (CO) was used with the instrument set to automatically shut off the PCB feed whenever the CO concentration exceeded 80 ppm (Figs 7 & 8). A Thermox WDG oxygen ($O_2$) analyzer was used to measure and record the $O_2$ concentration in the flue gas. Additionally, the Thermox WDG was set to automatically shut off the PCB feed whenever the $O_2$ concentration was less than 3% (Figs 8 & 9).

The operation of the temperature, carbon monoxide and oxygen cut-off mechanisms was demonstrated prior to the test.

By mutual agreement between Region 6 and RES(TX) the carbon dioxide concentration was measured by the Orsat Method in grab samples in lieu of continuous analysis with recording as specified in CFR 761.40-7, and, the required combustion efficiency in CFR 761.40-2 was increased from 99% to 99.9% (Appendix II).

## THE PCB INCINERATION TEST PROCEDURE

During the period October 25th through November 8th, 1979 RES(TX), Inc obtained from several local companies 52,900 kgs of PCB liquid wastes which were blended in a baffled and mechanically stirred tank (T-27). Analysis of a sample of this blend showed 470,000 mg/kg of PCB's and a specific gravity of 1.340: individual isomers were not identified but Arochlors 1254 and 1260 appeared to be predominant (Appendix V).

A liquid waste material (in storage tank T-60) was used as the auxiliary fuel for these tests as well as for the background test (Test 1), and its properties are shown in Table I, Test No 1. The PCB fuel used for the three PCB tests was prepared by blending 22,700 kgs of auxiliary fuel with the 52,900 kgs of PCB wastes in the blend-feed tank: the properties are shown in Table I.

During each test, grab samples were taken from the feed line (Fig 6) every 15 minutes and composited by consecutive two hour periods. Each composite sample was analyzed for PCB concentration, see Table I and Appendix V. Those composite samples were in turn composited as one sample for each test and analyzed for elemental composition, heat of combustion, ash content, chloride scrub and specific gravity (Table I).

During all tests auxiliary fuel was fed to the kiln at an average rate of 840 kg/hour. For Test No 1, the background test, auxiliary fuel was fed to the Loddby liquid burner at an average rate of 2,151 kg/hour. For the PCB tests, Numbers 2,3, and 4, the PCB fuel was fed at average rates of 3,253; 2,996; and 3,253 kg/hour, respectively (Table II).

While the tests were being made no other fuels were fed to either the kiln or the Loddby liquid burner. Moreover, each test was preceeded and followed by the incineration of only auxiliary fuel for periods of at least 30 minutes. Once the testing and auxiliary fuel flushing were completed, RES(TX), Inc reverted to the normal incineration of wastes.

During each test the following sampling programs pertained. Grab samples of the Loddby fuel were taken every fifteen minutes

(Figs 2 and 6). Grab samples of water streams were taken every thirty minutes: well water, lime slurry, touch-up tank (TUT) effluent (Fig 2) and Outfall 001 (Fig 1). Stack samples were taken during a 240 minute time period (Fig 3). Grab samples were taken from the hot duct approximately every two hours for carbon dioxide ($CO_2$) analysis by the Orsat Method (Fig 2).

## THE PCB INCINERATION TEST RESULTS

Only auxiliary fuel was used in the background test made on November 12, 1979. The average feed rate to the Loddby burner was 2,151 kg/hr for the 448 minute test period (Table II, Test No 1). The average temperatures in the afterburner and the hot duct were 1262° and 1183° C, respectively (Table III, Test No 1). With an average $CO_2$ concentration in the hot duct of 8.3 vol% and an average CO concentration in the stack of 0.9 ppm the combustion efficiency(7) was 99.999% (Tables IV and V).

No PCB's were detected in the auxiliary fuel (Table I, Test No 1), nor in the water streams (Table VI, Test No 1), nor in the stack gas (Table VII, Test No 1).

The replicate PCB-fuel incineration tests, Numbers 2,3, and 4, were made on November 13,14, and 15, respectively, with the following (average) conditions. The fuel had a PCB content of 34.8 wt% and a Heat of Combustion of 5,770 kcal/kg (Table I). The feed rate to the Loddby liquid burner was 3,170 kg/hr for 391 minutes (Table II). The temperatures in the afterburner and the hot duct were 1304° and 1183°C, respectively (Table III). A combustion efficiency of 99.993% was acheived with a $CO_2$ concentration of 9.1 vol% and a CO concentration of 6.9 ppm (Table IV).

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(7) Defined as $100 \times \{(CO_2) - (CO)\}/(CO_2)$.

The stack gas samples showed no detectable amounts of PCB's (Table VII). (The limit of detectability of PCB's is 1 ppb and no detectable amount of PCB's is reported as "less than 1 ppb" or, "<1 ppb") The input water samples showed no detectable PCB's in the well water and 1 ppb in the lime slurry (Table VI, Test Nos 2,3, and 4). The validity of the 4 ppb reported for the 3rd lime slurry composite in Test No 2 is questioned. The output water samples showed 1 ppb in the TUT effluent and no detectable PCB's in Outfall 001 water (Table VI, Test Nos 2,3, and 4).

Effluent water from Outfall 001 is regulated by Texas Department of Water Resources (TDWR) Permit No 01429 and by National Pollution Discharge Elimination System (NPDES) Permit No TX0005941. During the test period, November 12 through 17, 1979, the quality of Outfall 001 effluent water was in compliance with the limitations specified in both permits (Table XII).

Samples of stack gas were taken and analyzed according to the applicable U.S. EPA methods discussed in their Interim Report of February 10, 1978(8). As mentioned above, there were no PCB's detected nor were there any RC1 or chlorinated dibenzofurans. In the backbround test with only auxiliary fuel used, the stack gas emission rate was 15.34 kg/hr for particulate, 8.8 kg/hr for total chloride, 0.58 kg/hr for NOX and 3.8 kg/hr for $CO_2$. During the three tests with PCB-fuel being fed to the Loddby burner the average emission rates were 17.65 kg/hr for particulates, 27.7 kg/hr for total chloride, 0.64 kg/hr for NOX and 4.1 kg/hr for $CO_2$. (The data for each test is shown in Table VII).

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(8) Sampling Methods and Analytical Procedures Manual for PCB Disposal: Interim Report, Beard, J.H. III. and Schaum, J., Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C., February 10, 1978.

At the request of U.S. EPA Region 6 the stack gas sampling time period was set at 240 minutes to be able to demonstrate a PCB destruction efficiency of 99.99999%. As shown in Table IX the average destruction efficiency was >99.99997%.

The scrubber efficiency, calculated from total chloride, is shown in Table X for each test. For the background test, Test No 1, the efficiency was 98.8% and for the PCB tests the average efficiency was 98.4%.

The average residence time in the hot zone (Loddby chamber, afterburner and hot duct) was calculated as 2.68 seconds based on fan performance curves (Fig 12) and standard methods (Appendix III).

During all tests, the following data was continuously recorded: afterburner and hot duct temperatures (Fig 13); kiln temperature (Fig 14); carbon monoxide and oxygen concentrations (Fig 15); water flows to scrubber system (Fig 16); $\Delta P$ across Venturi throat (Fig 17); the pH of scrubber water retention tank (Fig 18); and, the pH of Outfall 001 outfall water (Fig 19).

## EQUIPMENT FLUSHING

PCB incineration Test No 4 was completed at 0108 hrs on November 16, 1979 and the remaining PCB fuel was incinerated under the prevailing conditions.

The tank trailer, blend-feed tank and all the auxiliary equipment used to transport, transfer, blend and feed the PCB fuel were flushed three times with auxiliary fuel and each flush was incinerated separately.

For the first flush 7500 kg of auxiliary fuel was pumped into the tank trailer which was then driven stop-and-go-wise for at least 30 minutes to slosh the fuel in the tank trailer. The flush fuel was pumped into the blend-feed tank and was fed to the Loddby liquid burner. This sequence was repeated once (second flush).

After the third tank trailer load of auxiliary fuel was pumped to the blend-feed tank an additional 48,900 kg of auxiliary fuel was pumped into the blend-feed tank for a final tank flush of 56,400 kg. During the incineration, three grab samples were taken from the feed line, each of which showed <1 mg/kg PCB's.

The data for the incineration of the excess PCB fuel and the three equipment flushes are shown in Table XIII and Figs 13, 14, 15, 16, 17, 18, and 19.

## ANALYTICAL PROCEDURES

Both the NUS and Environment One laboratories demonstrated their capability to analyze for PCB's using PCB test samples submitted by the U.S. EPA (Appendices II and VI).

NUS laboratories used the method in Attachment B in the U.S. EPA Interim Report.(8) The analyses for metals in the fuel feeds were made by Atomic Adsorption Spectroscopy using an IR-Model 251 AA Spectrophometer (Table VIII).

SPL laboratories sub-contracted the carbon-hydrogen analyses to Schwarzkopf Microanalytical Laboratory in Woodside, New York. The sulfur analyses were made using a Dohrman Microcoulombmeter: the results (Table I and Appendix IV) could be high because of positive chloride interference. The nitrogen content was determined by the Kjeldahl method. After the sample was digested in a Parr bomb, the chloride was determined by titration with silver nitrate solution.

NUS laboratories after extensive investigation concluded that no accepted procedure existed for the detection of trace amounts of polychlorinated dibenzofurans in PCB's (see letter NUS to RES, Appendix II).

## CONCLUSIONS

Liquid wastes containing 35% PCB's were incinerated with a destruction efficiency >99.99997% and a combustion efficiency of 99.993%. The Flexi-Venturi/bubble-cap tray absorber scrubbed the flue gas with a 98.4% efficiency, based on the chloride balance.

Continuous monitoring of the flue gas showed that the CO concentration was less than 12 ppm, the $O_2$ concentration was greater than 7%, and the minimum hot duct temperature was 1146°C.

The incineration dwell time was 2.68 seconds.

The effluent water quality at Outfall 001 was well below the specifications in the TDWR Permit No 01429 and the NPDES Permit No TX0005941. The quality of the flue gas emitted from the incinerator stack was below the specifications in TACB Permit No R-679.

All controllers, recorders, and automatic shut-offs required by CFR-761-40 and the Regional Administrator for U.S. EPA Region 6 were functional during the incineration tests.

## TABLE I

## PHYSICAL AND CHEMICAL PROPERTIES OF FEED STREAMS

### PCB Incineration Test November 12-16, 1979

| Run No. | Elemental Composition(a), wt% | | | | | Concentration of PCB's in Composited grab samples(b), X10$^3$ mg/kg | | | | Heat of Comb.(c) kcal/kg | Ash Content,(c) wt% | Chloride content of comb. gas(c) wt%. | Spec. grav. kg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | H | Cl | N | S | 1 | 2 | 3 | 4 | | | | |
| 1 | 63.65 | 8.86 | 24.2 | 0.072 | 0.072 | <0.001 | <0.001 | <0.001 | -- | 10,400 | 0.2 | 13 | 0.996 |
| 2 | 48.58 | 4.66 | 43.8 | 0.027 | 0.036 | 330 | 380 | 380 | -- | 6,700 | nd | 38 | 1.261 |
| 3 | 50.94 | 4.73 | 54.3 | 0.015 | 0.035 | 360 | 380 | 360 | -- | 5,700 | 0.7 | 54 | 1.189 |
| 4 | 50.44 | 4.80 | 56.3 | 0.016 | 0.034 | 325 | 340 | 310 | 310 | 4,900 | 0.5 | 50 | 1.261 |

(a). Analyses were made by SPL with the C/H subcontracted to Schwartzkopf Micro-analytical Lab.

(b). Analyses were made by NUS Laboratories.

(c). Analyses were made by RES (TX) Laboratory.

nd = none detected

## TABLE II

## FUEL FEED RATES DURING PCB INCINERATION TESTS

November 12-15, 1979

| Test No. | Duration of test,[a] mins | Total feed used,[b] liters | Average feed rate | |
|---|---|---|---|---|
| | | | liters/min | kg/hr |
| 1 | 448 | 16,065 | 36 | 2151 |
| 2 | 368 | 15,687 | 43 | 3253 |
| 3 | 390 | 16,519 | 42 | 2996 |
| 4 | 415 | 17,766 | 43 | 3253 |

(a). Duration of incineration of fuel was calculated from data log sheets reproduced in Appendix 1.

(b). Calculated from recorded gallons multiplied by 3.78 liters/gallon.

## TABLE III

## OPERATING TEMPERATURES DURING PCB INCINERATION TESTS(a)

November 12-15, 1979

| Test No. | Temperature, °C(b) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hot Duct | | | Afterburner | | | Kiln | | | Ambient | | |
| | Min | Max | Ave | Min | Max | Ave | Min | Max | Ave | Min | Max | Ave |
| 1 | 1161 | 1210 | 1183 | 1197 | 1301 | 1262 | 709 | 875 | 737 | 14.4 | 17.5 | 16.4 |
| 2 | 1113 | 1218 | 1178 | 1211 | 1338 | 1280 | 737 | 883 | 822 | 13.3 | 20.0 | 15.3 |
| 3 | 1147 | 1212 | 1186 | 1269 | 1360 | 1312 | 762 | 925 | 871 | 15.6 | 17.2 | 16.6 |
| 4 | 1148 | 1220 | 1184 | 1252 | 1396 | 1321 | 709 | 988 | 854 | 12.8 | 15.0 | 13.6 |

(a). Values shown were calculated from data in operating sheets reproduced in Appendix I.

(b). Conversion from °F to °C was made with the use of the temperature conversion table in Handbook of Chemistry, Lange, N.A., Ed., Handbook Publishers, Inc., Sandusky, Ohio, 1941.

## TABLE IV

## COMBUSTION EFFICIENCIES DURING PCB INCINERATION TESTS

November 12-15 , 1979

| Test No. | Clock time hrs | Carbon dioxide,[a] vol% | Carbon monoxide,[b] ppm | Combustion efficiency,[c] % |
|---|---|---|---|---|
| 1 | 1455 | 8.0 | 0.50 | 99.999375 |
| | 1640 | 8.0 | 0.00 | 100.000000 |
| | 1845 | 8.6 | 0.50 | 99.999419 |
| | 1950 | 8.4 | 1.75 | 99.997917 |
| | Average | | | 99.999 |
| 2 | 1515 | 9.8 | 6.5 | 99.993367 |
| | 1700 | 10.0 | 6.0 | 99.994000 |
| | 1905 | 9.2 | 4.5 | 99.995109 |
| | 2015 | 9.0 | 5.5 | 99.993889 |
| | Average | | | 99.994 |
| 3 | 1130 | 9.0 | 11.0 | 99.987778 |
| | 1245 | 9.2 | 10.5 | 99.988587 |
| | 1430 | 8.4 | 9.75 | 99.988393 |
| | 1630 | 8.2 | 9.0 | 99.989024 |
| | Average | | | 99.989 |
| 4 | 1845 | 9.6 | 6.0 | 99.993750 |
| | 2010 | 8.4 | 3.0 | 99.996429 |
| | 2150 | 9.2 | 5.5 | 99.994022 |
| | 2440 | 8.8 | 5.0 | 99.994318 |
| | Average | | | 99.995 |

(a). Data from Environmental One, Inc. report reproduced in Appendix IV. Samples of hot duct gas were analyzed for carbon dioxide by the Orsat method.

(b). Data from Operations data sheets reproduced in Appendix I.

(c). Defined in 40CFR 761.40 a2 as

$$\frac{(CO_2) - (CO)}{(CO_2)} \times 100$$

## TABLE V

## OPERATING TEMPERATURES, FLUE GAS CONCENTRATIONS AND AIR FLOWS: TEST NO. 1 (a)

| Clock time, hrs. | Temperature, C |  |  |  | Gas Monitor |  |  | Fan louvres, % open |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Afterburner | Hot Duct | Kiln | Ambient | CO, ppm | $O_2$, % | $CO_2$, %(b) | FD (c) | ID (c) |
| 1400 | 1301 | 1174 | 875 | 17.0 | 1.75 | 8.15 |  | 67 | 32 |
| 1415 | 1266 | 1190 | 767 | 17.0 | 1.50 | 8.15 |  | 67 | 32 |
| 1430 | 1206 | 1161 | 712 | 17.0 | 1.25 | 7.73 |  | 67 | 32 |
| 1445 | 1270 | 1178 | 730 | 17.0 | 0.50 | 7.94 |  | 67 | 32 |
| 1500 | 1255 | 1194 | 754 | 17.2 | 0.50 | 8.57 | 8.0 | 65 | 32 |
| 1515 | 1253 | 1196 | 754 | 17.2 | 1.00 | 8.57 |  | 65 | 32 |
| 1530 | 1254 | 1196 | 759 | 17.5 | 0.00 | 8.18 |  | 65 | 32 |
| 1545 | 1246 | 1188 | 727 | 17.5 | 0.00 | 8.57 |  | 65 | 32 |
| 1600 | 1237 | 1196 | 747 | 17.5 | 0.00 | 8.99 |  | 65 | 32 |
| 1615 | 1242 | 1195 | 748 | 17.2 | 0.75 | 8.57 |  | 65 | 32 |
| 1630 | 1242 | 1195 | 746 | 17.0 | 0.00 | 9.41 |  | 65 | 32 |
| 1645 | 1242 | 1195 | 749 | 16.7 | 0.00 | 9.41 | 8.0 | 65 | 34 |
| 1700 | 1253 | 1191 | 719 | 16.4 | 0.00 | 9.82 |  | 65 | 34 |
| 1715 | 1290 | 1203 | 709 | 16.1 | 0.00 | 9.82 |  | 65 | 33 |
| 1730 | 1229 | 1183 | 746 | 16.1 | 0.00 | 10.24 |  | 65 | 34 |
| 1745(d) | 1197 | 942 | 437 | 16.1 | 6.0 | 10.24 |  | 65 | 32 |
| 1800 | 1292 | 1210 | 816 | 16.1 | 0.00 | 10.24 |  | 65 | 34 |
| 1815 | 1296 | 1175 | 710 | 16.1 | 0.50 | 9.82 |  | 65 | 33 |
| 1830 | 1262 | 1201 | 741 | 16.1 | 1.00 | 10.87 |  | 65 | 33 |
| 1845 | 1272 | 1192 | 738 | 16.1 | 0.50 | 10.45 | 8.6 | 65 | 33 |
| 1900 | 1278 | 1199 | 738 | 16.1 | 1.25 | 10.87 |  | 65 | 34 |
| 1915 | 1288 | 1201 | 752 | 16.1 | 1.00 | 10.45 |  | 65 | 33 |
| 1930 | 1266 | 1203 | 746 | 15.8 | 1.00 | 11.08 |  | 65 | 32 |
| 1945 | 1280 | 1196 | 753 | 15.6 | 0.50 | 10.24 | 8.4 | 65 | 33 |
| 2000 | 1278 | 1195 | 750 | 15.6 | 1.75 | 10.45 |  | 65 | 30 |
| 2015 | 1276 | 1196 | 746 | 15.0 | 1.50 | 10.03 |  | 65 | 30 |
| 2030 | 1282 | 1196 | 740 | 14.7 | 1.75 | 10.03 |  | 65 | 30 |
| 2045 | 1280 | 1198 | 737 | 14.4 | 2.25 | 10.24 |  | 65 | 31 |

(a) Summarized from original data sheets reproduced in Appendix I.
(b) Hot duct gas analysis for carbon dioxide by Orsat method.
(c) FD = forced draft fan; ID = induced draft fan.
(d) At 1738 hrs. a line plug stopped feed and decreased temperatures. Temperature shut-down activated at 1119°

## TABLE V (cont.)

### OPERATING TEMPERATURES, FLUE GAS CONCENTRATIONS AND AIR FLOWS: TEST NO. 3 (a)

| Clock time, hrs. (d) | Temperature, °C |  |  |  | Gas Monitor |  |  | Fan louvres, % open |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Afterburner | Hot Duct | Kiln | Ambient | CO, ppm | $O_2$, % | $CO_2$, %(b) | FD(c) | ID (c) |
| 1045 | 1342 | 1147 | 762 | 15.6 | 14.0 | 7.11 |  | 70 | 18 |
| 1100 | 1350 | 1188 | 881 | 15.6 | 14.0 | 7.32 |  | 70 | 18 |
| 1115 | 1360 | 1203 | 882 | 15.6 | 12.0 | 7.32 |  | 70 | 19 |
| 1130 | 1342 | 1198 | 878 | 16.1 | 11.0 | 7.73 | 9.0 | 70 | 19 |
| 1145 | 1348 | 1198 | 876 | 16.4 | 11.0 | 7.32 |  | 70 | 19 |
| 1200 | 1343 | 1203 | 881 | 16.4 | 11.5 | 7.73 |  | 70 | 19 |
| 1215 | 1338 | 1203 | 867 | 16.4 | 11.0 | 7.84 |  | 70 | 19 |
| 1230 | 1339 | 1201 | 885 | 16.4 | 11.0 | 7.84 |  | 70 | 18 |
| 1245 | 1335 | 1198 | 856 | 16.1 | 10.5 | 8.15 | 9.2 | 70 | 18 |
| 1300 | 1338 | 1203 | 870 | 16.4 | 11.0 | 8.15 |  | 70 | 19 |
| 1315 | 1335 | 1204 | 865 | 16.7 | 10.0 | 7.94 |  | 70 | 19 |
| 1330 | 1325 | 1194 | 860 | 16.7 | 9.0 | 8.15 |  | 70 | 19 |
| 1345 | 1329 | 1212 | 877 | 16.7 | 9.0 | 8.36 |  | 70 | 20 |
| 1400 | 1298 | 1195 | 873 | 17.0 | 10.5 | 9.41 |  | 70 | 22 |
| 1415 | 1271 | 1178 | 859 | 16.7 | 11.0 | 9.82 |  | 70 | 22 |
| 1430 | 1273 | 1174 | 878 | 16.4 | 9.75 | 9.61 | 8.4 | 70 | 21 |
| 1445 | 1275 | 1173 | 881 | 15.6 | 9.5 | 9.82 |  | 70 | 22 |
| 1500 | 1277 | 1179 | 884 | 16.7 | 9.5 | 9.41 |  | 70 | 22 |
| 1515 | 1284 | 1180 | 881 | 17.0 | 9.0 | 9.82 |  | 70 | 22 |
| 1530 | 1277 | 1173 | 850 | 17.2 | 7.0 | 10.66 |  | 70 | 23 |
| 1545 | 1272 | 1171 | 838 | 17.2 | 8.0 | 10.45 |  | 70 | 22 |
| 1600 | 1283 | 1177 | 856 | 17.2 | 9.0 | 10.66 |  | 70 | 22 |
| 1615 | 1278 | 1175 | 843 | 17.2 | 9.0 | 11.91 |  | 70 | 22 |
| 1630 | 1278 | 1175 | 893 | 17.2 | 9.0 | 10.87 | 8.2 | 70 | 22 |
| 1645 | 1269 | 1172 | 925 | 17.2 | 9.0 | 10.24 |  | 70 | 22 |
| 1700 | 1304 | 1187 | 887 | 16.7 | 9.0 | 9.82 |  | 70 | 22 |
| 1715(e) | 1321 | 1157 | 878 | 16.7 | 8.0 | 8.36 |  | 70 | 23 |
| 1730 | 1341 | 1199 | 872 | 16.4 | 7.0 | 8.98 |  | 70 | 23 |

(a) Summarized from original data sheets reproduced in Appendix I.
(b) Hot duct gas analysis for carbon dioxide by Orsat method.
(c) FD = forced draft fan; ID = induced draft fan.
(d) On PCB feed at 1030 hrs.; low temperature shut-off at 1034 hrs. then on at 1042 hrs.
(e) Off PCB fuel at 1708 hrs: remainder of time on background fuel purge.

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## TABLE V (cont.)

### OPERATING TEMPERATURES, FLUE GAS CONCENTRATIONS AND AIR FLOWS: TEST NO. 2 (a)

| Clock Time, hrs. | Temperature, °C Afterburner | Hot Duct | Kiln | Ambient | Gas Monitor CO, ppm | O₂, % | CO₂, % (b) | Fan louvres, % open FD (c) | ID (c) |
|---|---|---|---|---|---|---|---|---|---|
| 1430 | 1243 | 1154 | 772 | 20.0 | 4.5 | 7.32 | | 72 | 20 |
| 1445 | 1243 | 1204 | 830 | 19.4 | 6.0 | 7.32 | | 70 | 23 |
| 1500 | 1246 | 1218 | 773 | 19.2 | 4.0 | 7.32 | | 70 | 20 |
| 1515 | 1227 | 1216 | 760 | 18.3 | 6.5 | 7.73 | 9.8 | 70 | 20 |
| 1530 | 1211 | 1195 | 747 | 18.1 | 6.0 | 8.15 | | 70 | 22 |
| 1545 | 1215 | 1184 | 771 | 17.2 | 5.5 | 8.15 | | 70 | 20 |
| 1600 (d) | 1221 | 1177 | 783 | 17.0 | 5.0 | 8.90 | | 70 | 20 |
| 1615 | 1225 | 1113 | 737 | 16.4 | 4.0 | 9.20 | | 70 | 20 |
| 1630 | 1264 | 1206 | 812 | 15.8 | 5.5 | 7.73 | | 70 | 20 |
| 1645 | 1286 | 1194 | 844 | 15.6 | 5.0 | 8.36 | | 70 | 23 |
| 1700 | 1292 | 1190 | 828 | 15.3 | 6.0 | 8.36 | 10.0 | 70 | 21 |
| 1715 | 1316 | 1173 | 838 | 15.0 | 5.5 | 8.36 | | 70 | 20 |
| 1730 | 1288 | 1168 | 826 | 14.4 | 5.0 | 9.20 | | 70 | 22 |
| 1745 | 1286 | 1147 | 835 | 14.4 | 5.0 | 9.41 | | 70 | 20 |
| 1800 | 1304 | 1169 | 845 | 14.2 | 6.5 | 9.20 | | 70 | 20 |
| 1815 | 1315 | 1179 | 846 | 13.9 | 6.0 | 8.57 | | 70 | 20 |
| 1830 | 1309 | 1184 | 878 | 13.9 | 5.0 | 8.57 | | 70 | 20 |
| 1845 | 1302 | 1181 | 870 | 13.9 | 4.0 | 8.78 | | 70 | 20 |
| 1900 | 1298 | 1172 | 862 | 13.9 | 4.5 | 8.99 | 9.2 | 70 | 20 |
| 1915 | 1307 | 1195 | 851 | 13.9 | 5.0 | 8.78 | | 70 | 21 |
| 1930 | 1311 | 1177 | 873 | 13.6 | 5.5 | 8.78 | | 70 | 20 |
| 1945 | 1300 | 1165 | 858 | 13.6 | 5.5 | 9.41 | | 70 | 20 |
| 2000 | 1293 | 1157 | 865 | 13.9 | 6.0 | 9.41 | | 70 | 20 |
| 2015 | 1297 | 1155 | 872 | 13.6 | 5.5 | 9.41 | 9.0 | 70 | 20 |
| 2030 | 1320 | 1165 | 873 | 13.3 | 5.5 | 8.78 | | 70 | 20 |
| 2045 (e) | 1338 | 1193 | 883 | 13.3 | 5.0 | 8.57 | | 70 | 20 |
| 2100 | 1298 | 1206 | 773 | 13.3 | 4.5 | 9.41 | | 70 | 20 |
| 2115 | 1280 | 1199 | 740 | 13.3 | 5.5 | 9.20 | | 70 | 20 |

(a) Summerized from original data sheets reproduced in Appendix I.
(b) Hot duct gas analysis for carbon dioxide by Orsat method.
(c) FD = force draft fan; ID = induced draft fan.
(d) PCB sample collection train plugged: PCB flow off at 1605 hrs. then on at 1625 hrs.
(e) Off PCB fuel at 2050 hrs.: remainder of time on background fuel purge.

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## TABLE V (cont.)

### OPERATING TEMPERATURES, FLUE GAS CONCENTRATIONS AND AIR FLOWS: TEST NO. 4 (a)

| Clock time, hrs. | Temperature, °C |  |  |  | Gas Monitor |  |  | Fan louvres, % open (c) |  |
|---|---|---|---|---|---|---|---|---|---|
|  | Afterburner | Hot Duct | Kiln | Ambient | CO, ppm | $O_2$, % | $CO_2$, % (b) | FD | ID (c) |
| 1800 | 1381 | 1159 | 821 | 15.0 | 2.5 | 7.73 |  | 68 | 30 |
| 1815 | 1384 | 1191 | 928 | 15.0 | 4.0 | 7.72 |  | 68 | 30 |
| 1830 | 1396 | 1202 | 949 | 15.0 | 6.0 | 8.56 |  | 68 | 30 |
| 1845 | 1370 | 1207 | 954 | 14.7 | 6.0 | 8.56 | 9.6 | 68 | 30 |
| 1900 | 1311 | 1171 | 956 | 14.4 | 5.0 | 8.78 |  | 68 | 30 |
| 1915 | 1424 | 1206 | 925 | 14.4 | 6.0 | 7.32 |  | 68 | 30 |
| 1930 | 1377 | 1205 | 934 | 14.2 | 6.0 | 8.56 |  | 68 | 30 |
| 1945 | 1359 | 1203 | 949 | 13.9 | 5.0 | 8.78 |  | 68 | 30 |
| 2000 | 1331 | 1148 | 730 | 13.9 | 4.0 | 8.78 |  | 68 | 30 |
| 2015 | 1350 | 1189 | 972 | 13.6 | 3.0 | 8.78 |  | 68 | 30 |
| 2030 | 1334 | 1182 | 984 | 13.6 | 4.0 | 8.78 | 8.4 | 68 | 30 |
| 2045 | 1363 | 1185 | 946 | 13.3 | 5.0 | 9.41 |  | 68 | 30 |
| 2100 | 1354 | 1194 | 941 | 13.3 | 6.0 | 8.56 |  | 68 | 30 |
| 2115 | 1314 | 1162 | 827 | 13.3 | 5.5 | 9.00 |  | 68 | 30 |
| 2130 | 1315 | 1161 | 888 | 13.3 | 5.0 | 9.41 |  | 68 | 30 |
| 2145 | 1326 | 166 | 988 | 13.3 | 5.5 | 9.00 |  | 68 | 30 |
| 2200 | 1304 | 1171 | 909 | 13.3 | 5.0 | 8.78 |  | 68 | 30 |
| 2215(d) | 1384 | 1168 | 911 | 13.1 | 4.0 | 10.03 | 9.2 | 68 | 28 |
| 2238 | 1390 | 1276 | 750 | 12.8 | 100+ | 10.87 |  | 68 | 27 |
| 2245 | 1252 | 1180 | 732 | 12.8 | 5.0 | 7.82 |  | 68 | 26 |
| 2300 | 1258 | 1170 | 797 | 12.8 | 6.0 | 11.29 |  | 68 | 25 |
| 2315 | 1300 | 1205 | 767 | 13.3 | 6.5 | 8.78 |  | 71 | 25 |
| 2330 | 1252 | 1161 | 725 | 13.1 | 5.5 | 10.00 |  | 71 | 25 |
| 2345 | 1326 | 1220 | 782 | 12.8 | 7.0 | 10.66 |  | 71 | 26 |
| 2400 | 1281 | 1201 | 761 | 12.8 | 6.0 | 8.57 |  | 72 | 25 |
| 2415 | 1257 | 1187 | 731 | 13.3 | 5.5 | 9.82 |  | 72 | 25 |
| 2430 | 1255 | 1183 | 731 | 13.3 | 5.0 | 10.24 |  | 72 | 25 |
| 2445 | 1252 | 1176 | 720 | 13.3 | 5.0 | 10.24 |  | 72 | 25 |
| 0100 | 1248 | 1175 | 709 | 12.8 | 6.5 | 10.45 | 8.8 | 72 | 25 |
|  |  |  |  |  |  | 10.24 |  | 72 | 25 |

(a) Summarized from original data sheets reproduced in Appendix I..
(b) Hot duct gas analysis for carbon dioxide by Orsat method.
(c) FD = forced draft fan; ID = induced draft fan.
(d) Off PCB fuel at 2212 hrs., on PCB fuel at 2227 hrs.

## TABLE VI

### ANALYSES OF WATER STREAMS: TEST NO. 1

| | Composite No. (a) | PCB conc, (b) ppb | Chloride conc, (c) mg/1 | Sulfate conc, (c) mg/1 | $p^H$(c)(d) | TDS(c)(e) mg/1 | TOC, (c)(f) mg/1 |
|---|---|---|---|---|---|---|---|
| Well water | 1 | < 1 | < 40 | nd | 8.1 | 300 | 34 |
| | 2 | < 1 | < 40 | nd | 7.9 | 310 | 15 |
| | 3 | < 1 | 50 | 25 | 7.3 | 350 | 53 |
| | 4 | -- | -- | -- | -- | -- | -- |
| | 5 | -- | -- | -- | -- | -- | -- |
| Lime slurry feed | 1 | < 1 | | | | | |
| | 2 | < 1 | | | | | |
| | 3 | < 1 | | | | | |
| | 4 | -- | | | | | |
| | 5 | -- | | | | | |
| TUF effluent | 1 | < 1 | 4499 | 105 | 3.8 | 8200 | 4 |
| | 2 | < 1 | 4300 | 140 | 2.9 | 7550 | 3 |
| | 3 | < 1 | 4300 | 140 | 7.9 | 8450 | 19 |
| | 4 | -- | -- | -- | -- | -- | -- |
| | 5 | -- | -- | -- | -- | -- | -- |
| Outfall 001 | 1 | < 1 | 3800 | 85 | 6.9 | 6900 | 4 |
| | 2 | < 1 | 3900 | 125 | 7.0 | 7200 | 8 |
| | 3 | < 1 | 3699 | 102 | 7.4 | 7000 | 4 |
| | 4 | -- | -- | -- | -- | -- | -- |
| | 5 | -- | -- | -- | -- | -- | -- |

a. Grab samples collected every 30 minutes were composited by consecutive 2 hour periods.
b. Analyses were made by NUS Laboratories.
c. Analyses were made by RES(Tx) laboratories.
d. Standard units via glass electrode.
e. TDS = total dissolved solids.
f. TOC = total organic carbon.

## TABLE VI (cont'd)
## ANALYSES OF WATER STREAMS: TEST NO. 2

| | Composite No. (a) | PCB conc, (b) ppb | Chloride conc, (c) mg/l | Sulfate conc, (c) mg/l | pH(c)(d) | TDS(c)(e) mg/l | TOC, (c)(f) mg/l |
|---|---|---|---|---|---|---|---|
| Well water | 1 | < 1 | -- | -- | -- | -- | -- |
| | 2 | < 1 | 200 | 5 | 8.5 | 790 | 42 |
| | 3 | < 1 | 50 | 40 | 8.2 | 392 | 36 |
| | 4 | -- | | | -- | -- | -- |
| | 5 | -- | | | -- | -- | -- |
| Lime slurry feed | 1 | 1 | | | | | |
| | 2 | < 1 | | | | | |
| | 3 | 4 | | | | | |
| | 4 | -- | | | | | |
| | 5 | -- | | | | | |
| TUT effluent | 1 | 1 | 7189 | 90 | 1.9 | 12200 | 83 |
| | 2 | < 1 | 7498 | 95 | 2.3 | 12550 | 61 |
| | 3 | 1 | 7800 | 85 | 11.3 | 15350 | 7 |
| | 4 | -- | -- | -- | -- | -- | -- |
| | 5 | -- | -- | -- | -- | -- | -- |
| Outfall 001 | 1 | 2 | 4200 | 95 | 7.4 | 6900 | 129 |
| | 2 | < 1 | 4200 | 120 | 7.1 | 7550 | 92 |
| | 3 | < 1 | 4300 | 110 | -- | 7200 | 46 |
| | 4 | -- | -- | -- | -- | -- | -- |
| | 5 | -- | -- | -- | -- | -- | -- |

a. Grab samples collected every 30 minutes were composited by consecutive 2 hour periods.
b. Analyses were made by NUS Laboratories.
c. Analyses were made by RES(Tx) laboratories.
d. Standard units via glass electrode.
e. TDS = total dissolved solids.
f. TOC - total organic carbon.

## TABLE VI (cont'd)
## ANALYSES OF WATER STREAMS: TEST NO. 3

| | Composite No. (a) | PCB conc, (b) ppb | Chloride conc, (c) mg/l | Sulfate conc, (c) mg/l | pH(c)(d) | TDS(c)(e) mg/l | TOC, (c)(f) mg/l |
|---|---|---|---|---|---|---|---|
| Well water | 1 | < 1 | 50 | 30 | 8.5 | 480 | 118 |
| | 2 | 1 | -- | -- | -- | -- | -- |
| | 3 | < 1 | 5000 | 95 | 8.7 | 7824 | 82 |
| | 4 | -- | -- | -- | -- | -- | -- |
| | 5 | -- | -- | -- | -- | -- | -- |
| Lime slurry feed | 1 | 1 | | | | | |
| | 2 | 1 | | | | | |
| | 3 | ( ) | | | | | |
| | 4 | -- | | | | | |
| | 5 | -- | | | | | |
| TUT effluent | 1 | < 1 | 7898 | 82 | 3.4 | 14400 | 88 |
| | 2 | 2 | 9497 | 105 | 8.1 | 13650 | 88 |
| | 3 | 1 | 5498 | 95 | 8.7 | 7800 | 82 |
| | 4 | -- | -- | -- | -- | -- | -- |
| | 5 | -- | -- | -- | -- | -- | -- |
| Outfall 001 | 1 | < 1 | 4697 | 88 | 7.2 | 8200 | 60 |
| | 2 | 1 | 4700 | 125 | 8.3 | 13400 | 101 |
| | 3 | < 1 | 4750 | 50 | 8.4 | 7650 | 207 |
| | 4 | -- | -- | -- | -- | -- | -- |
| | 5 | -- | -- | -- | -- | -- | -- |

a. Grab samples collected every 30 minutes were composited by consecutive 2 hour periods.
b. Analyses were made by NUS Laboratories.
c. Analyses were made by RES(Tx) laboratories.
d. Standard units via glass electrode.
e. TDS = total dissolved solids.
f. TOC - total organic carbon.

### TABLE VI (cont'd)
### ANALYSES OF WATER STREAMS: TEST NO. 4

| | Composite No. (a) | PCB conc, (b) ppb | Chloride conc, (c) mg/1 | Sulfate conc, (c) mg/1 | pH(c)(d) | TDS(c)(e) mg/1 | TOC, (c)(f) mg/1 |
|---|---|---|---|---|---|---|---|
| Well water | 1 | < 1 | 400 | nd | 8.5 | 360 | 122 |
| | 2 | 2 | 300 | nd | 7.7 | 390 | 107 |
| | 3 | 1 | 55 | 40 | 7.9 | 352 | 61 |
| | 4 | 1 | 40 | 30 | 8.2 | 308 | 6 |
| | 5 | -- | -- | -- | -- | -- | -- |
| Lime slurry feed | 1 | < 1 | | | | | |
| | 2 | 2 | | | | | |
| | 3 | 2 | | | | | |
| | 4 | 1 | | | | | |
| | 5 | -- | | | | | |
| TUT effluent | 1 | < 1 | 8597 | 95 | 9.9 | 11800 | 54 |
| | 2 | 1 | 7998 | 85 | 10.2 | 13800 | 57 |
| | 3 | 1 | 8997 | 62 | 10.8 | 13840 | 44 |
| | 4 | 2 | 8400 | 105 | 8.5 | 8400 | 114 |
| | 5 | 2 | -- | -- | -- | -- | -- |
| Outfall 001 | 1 | < 1 | 5400 | 65 | 6.1 | 9250 | 130 |
| | 2 | 1 | 5300 | 75 | 6.8 | 10100 | 38 |
| | 3 | 1 | 5198 | 75 | 7.0 | 9500 | 12 |
| | 4 | < 1 | 5800 | 85 | 6.3 | 8250 | 29 |
| | 5 | -- | -- | -- | -- | -- | -- |

a. Grab samples collected every 30 minutes were composited by consecutive 2 hour periods.
b. Analyses were made by NUS Laboratories.
c. Analyses were made by RES(Tx) laboratories.
d. Standard units via glass electrode.
e. TDS = total dissolved solids.
f. TOC - total organic carbon.

## TABLE VII

## CONCENTRATION OF CERTAIN COMPONENTS IN THE FLUE GAS

## DURING THE PCB INCINERATION TESTS(a)

| Component | Concentration, kg/hr<br>Test 1(b) | Test 2(c) | Test 3(c) | Test 4(c) |
|---|---|---|---|---|
| PCB's | nd | nd | nd | nd |
| RCI's | nd | nd | nd | nd |
| Benzofurans(d) | nd | nd | nd | nd |
| Particulates(e) | 15.34 | 19.55 | 18.11 | 15.28 |
| Total chloride(f) | 8.8 | 28.5 | 28.6 | 26.1 |
| NOX(g) | 0.58 | 0.63 | 0.58 | 0.71 |
| Carbon dioxide(h) | 3.8 | 4.3 | 4.0 | 4.1 |

(a). Sampling and analyses of flue gas were made by Environment One Corp.
(b). During Test 1 only background fuel was incinerated.
(c). During this Test the PCB feed was as described in Table I.
(d). Polychlorinated dibenzofurans.
(e). Analyzed by EPA Method 5.
(f). Analyzed according to "Sampling Methods & Analytical Procedures Manual for PCB Disposal," Feb.10,1978.
(g). Analyzed by EPA Method 7.
(h). Values are average of 4 grab samples taken from the hot duct and analyzed by the Orsat method.

## TABLE VIII

## METAL CONCENTRATION IN THE INCINERATOR FEED DURING THE PCB INCINERATION TESTS

November 12-15, 1979

| Metal[b] | Concentration, mg/1[a]<br>Test 1 | Test 2 | Test 3 | Test 4 |
|---|---|---|---|---|
| Barium | <4 | <4 | <4 | <4 |
| Cadmium | <2 | <2 | <2 | <2 |
| Chromium | 84 | 8 | 7 | 6.8 |
| Copper | 4.4 | <2 | <2 | <2 |
| Lead | <2 | 24 | 34 | 34 |
| Manganese | <2 | <2 | <2 | <2 |
| Nickel | <2 | <2 | <2 | <2 |
| Silver | <2 | <2 | <2 | <2 |
| Zinc | 5.8 | <2 | <2 | <2 |

(a). Analyses were made by NUS laboratories.

(b). Standards were prepared from organo-metallic compounds and xylene. For the standards 5 mls were dissolved in 100 mls of xylene.

## TABLE IX

## PCB DESTRUCTION EFFICIENCIES DURING PCB INCINERATION TEST[(a)]

| Run No. | PCB input,[(b)] Kilograms | PCB ouput: In flue gas,[(c)] ppb | PCB ouput: In TUT water,[(d)] ppb | PCB ouput: Total kilograms | Destruction efficiency,[(e)] % |
|---|---|---|---|---|---|
| 1 | $<10^{-12}$ | <1 | <1 | ------ | --------- |
| 2 | 4723 | <1 | 1 | 0.0011 | >99.999977 |
| 3 | 4398 | <1 | 1.3 | 0.0014 | >99.999968 |
| 4 | 4177 | <1 | 1.4 | 0.0015 | >99.999964 |
| | | | | AVERAGE | >99.999970 |

(a). Based on the 240 min. PCB stack sampling time period.

(b). Calculated from the flow rates in Table II and the concentrations in Table I.

(c). Values reported in Environment One report (Appendix IV ) and shown in TableVII.

(d). For the purpose of this calculation all values in TableVI, except Run no.#1, shown as <1 (below detectable limit) were taken as 1.

(e). Destruction efficiency is defined as {(input - output) / (input)}100. Since the condition in (d) was used the efficiencies are reported as greater than (>) the calculated value.

## TABLE X

## SCRUBBER EFFICIENCY BASED ON CHLORIDE-BALANCE DURING THE PCB INCINERATION TESTS

### November 12-15, 1979

| Run No. | Chloride input,[a] kg/hr |  | Chloride output, kg/hr | Scrubber efficiency,[c] wt% |
|---|---|---|---|---|
|  | PCB fuel to Loddby | Auxiliary fuel to kiln | Flue gas[b] |  |
| 1 | 519[d] | 183 | 8.8 | 98.8 |
| 2 | 1413 | 183 | 28.5 | 98.2 |
| 3 | 1641 | 183 | 28.6 | 98.4 |
| 4 | 1824 | 183 | 26.1 | 98.7 |

(a). Chloride analyses by SPL and recorded in Table 1.

(b). Chloride analyses by Environment One and recorded in Table VII.

(c). Define as [(Input-Output)/Input]100.

(d). Auxiliary fuel was fed to the Loddby during this background test.

# TABLE XI

## INCINERATION RESIDENCE TIME DURING PCB INCINERATION TESTS

November 12-15, 1979

| Run no. | Average Temp Hot Zone, °R | Density flue gas,[(a)] lbs/cu ft | Weight of flue gas,[(b)] lbs | Residence time,[(c)] sec |
|---|---|---|---|---|
| 1 | 2763 | 0.0144 | 122.1 | 2.74 |
| 2 | 2796 | 0.0142 | 120.4 | 2.71 |
| 3 | 2853 | 0.0139 | 117.8 | 2.65 |
| 4 | 2870 | 0.0138 | 117.0 | 2.63 |

(a) Calculated from the formula in #4.2 in Sampling Methods and Analytical Procedures Manual for PCB Disposal: Interim Report, Beard, J.H., Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C., February 10, 1978.

(b) Calculated from Density of flue gas and the volume of the hot zone (Loddby burner, after-burner and hot duct) at 8476 cu. ft.

(c) Calculated from the weight of flue gas in the hot zone and the mass flow rate of the flue gas (See Appendix III).

## TABLE XII

## QUALITY OF OUTFALL 001 EFFLUENT DURING THE PCB INCINERATION TEST

### Week of November 12, 1979

| Parameter | Limits, kg/day | | | | November, 1979[c] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | NPDES[a] | | TDWR[b] | | | | | | | |
| | Daily Av. | Daily Max | Daily Av. | Daily Max | 12 | 13 | 14 | 15 | 16 | 17 |
| $BOD_5$[d] | ---- | ---- | 70 | 140 | -- | nd | -- | nd | -- | -- |
| TSS[e] | 132 | 263 | 103 | 205 | -- | 9.6 | -- | 12.7 | -- | 5.5 |
| TOC[f] | 184 | 368 | 184 | 369 | -- | (g) | -- | 25.5 | -- | 10.5 |
| Oil/Grease | 30 | 60 | 30 | 60 | -- | 3.6 | -- | 0.3 | -- | 0.4 |
| Phenolics | 0.09 | 0.18 | 0.09 | 0.18 | -- | 0.03 | -- | nd | -- | nd |
| pH | 6 to 9, continuous record[h] | | | | -- | 7.1/8.0 | 7.4/8.1 | 7.4/7.5 | 7.6/8.3 | 6.8/8.3 |

(a) According to NPDES Permit No. TX0005941.
(b) According to TDWR Permit No. 01429
(c) Values found by RES(TX) laboratory using accepted analytical procedures.
(d) Biochemical Oxygen Demand-5 day.
(e) Total Suspended Solids.
(f) Total Organic Carbon.
(g) TOC instrument unstable, no reliable result available.
(h) Each day the minimum and maximum values shown on the strip chart are recorded.

## TABLE XIII

### PCB CONCENTRATION IN THE FINAL EQUIPMENT FLUSH USING AUXILIARY FUEL

November 17, 1979 from 1630 to 1315 hrs.

| Sample no[a] | NUS sample no[b] | Total PCB concentration mg/kg |
|---|---|---|
| 1 | 29110326 | <1 |
| 2 | 29110327 | <1 |
| 3 | 29110328 | <1 |

(a). Grab samples were taken from the feed line when the feed tank was almost full, about half-full, and about one-fourth full.

(b). Analyses were made by NUS laboratories.

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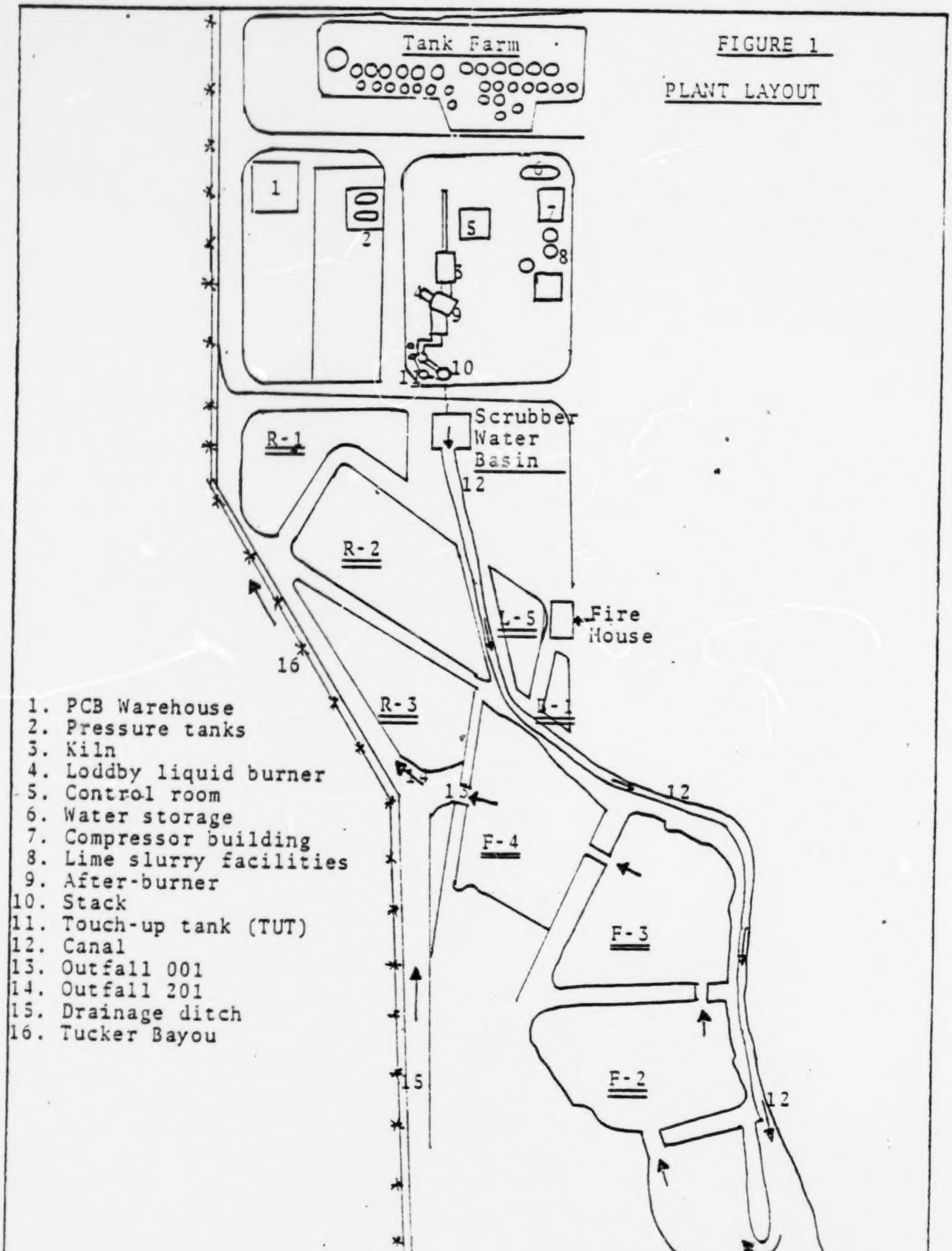
FIGURE 1

PLANT LAYOUT



1. PCB Warehouse
2. Pressure tanks
3. Kiln
4. Loddby liquid burner
5. Control room
6. Water storage
7. Compressor building
8. Lime slurry facilities
9. After-burner
10. Stack
11. Touch-up tank (TUT)
12. Canal
13. Outfall 001
14. Outfall 201
15. Drainage ditch
16. Tucker Bayou

FIGURE 2

SCHEMATIC OF INCINERATOR COMPLEX

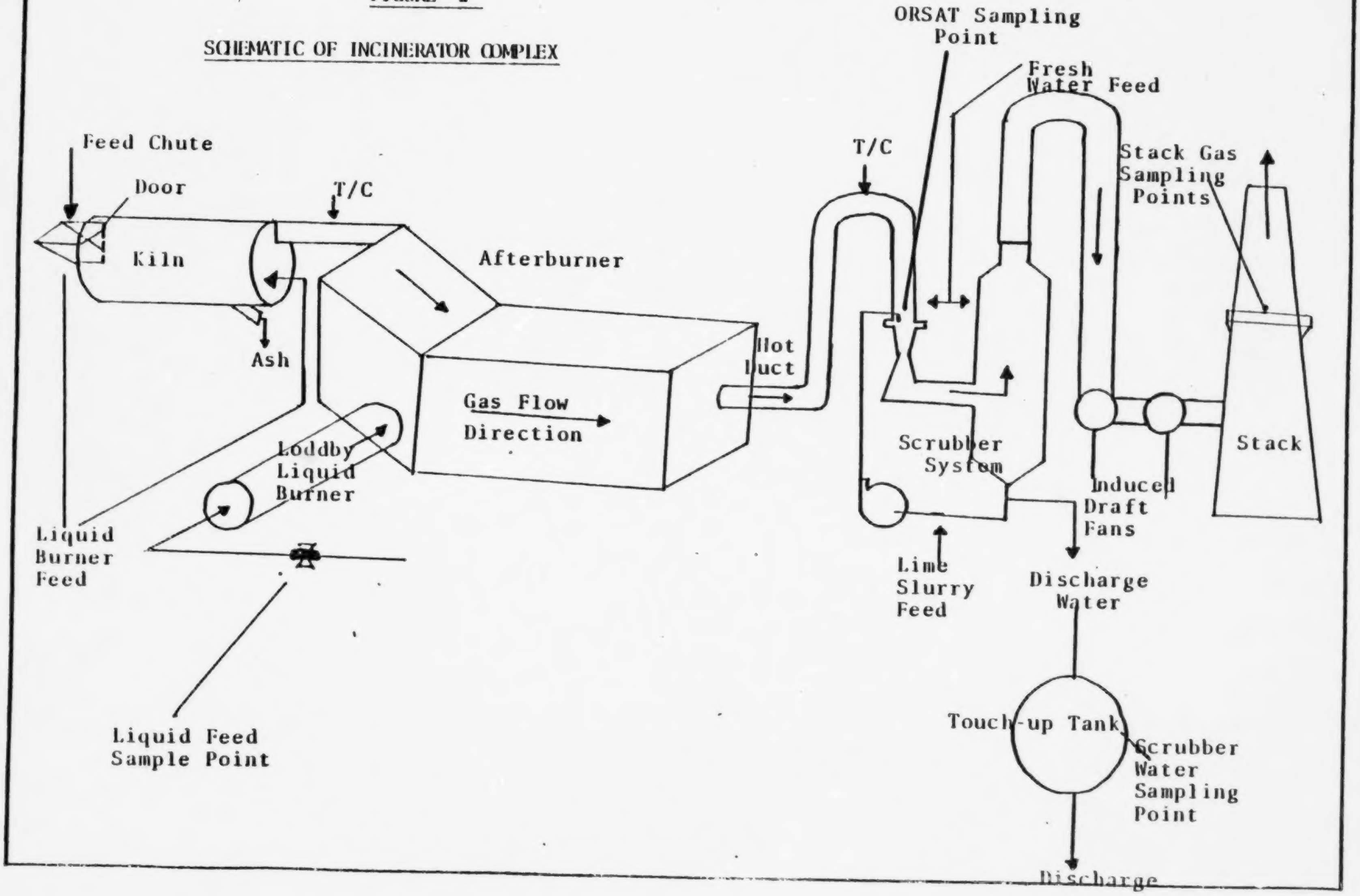


FIGURE 3

SCHEMATIC OF INCINERATOR STACK

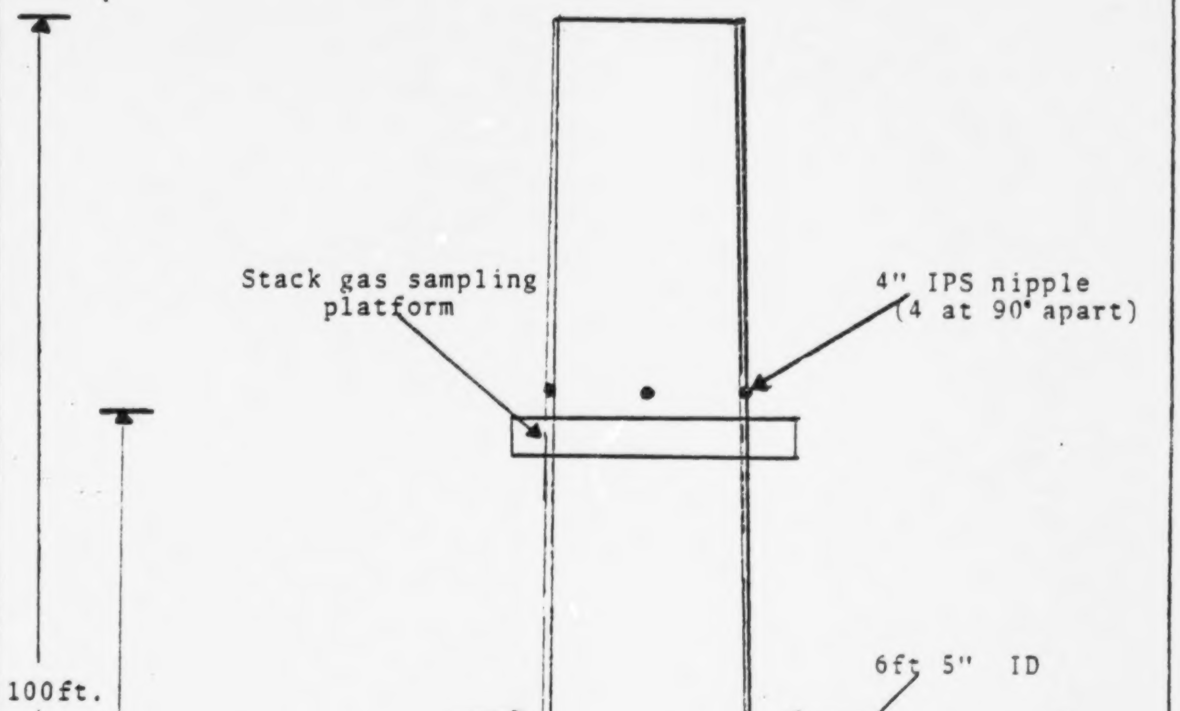


FIGURE 4

SCHEMATIC OF HOT DUCT

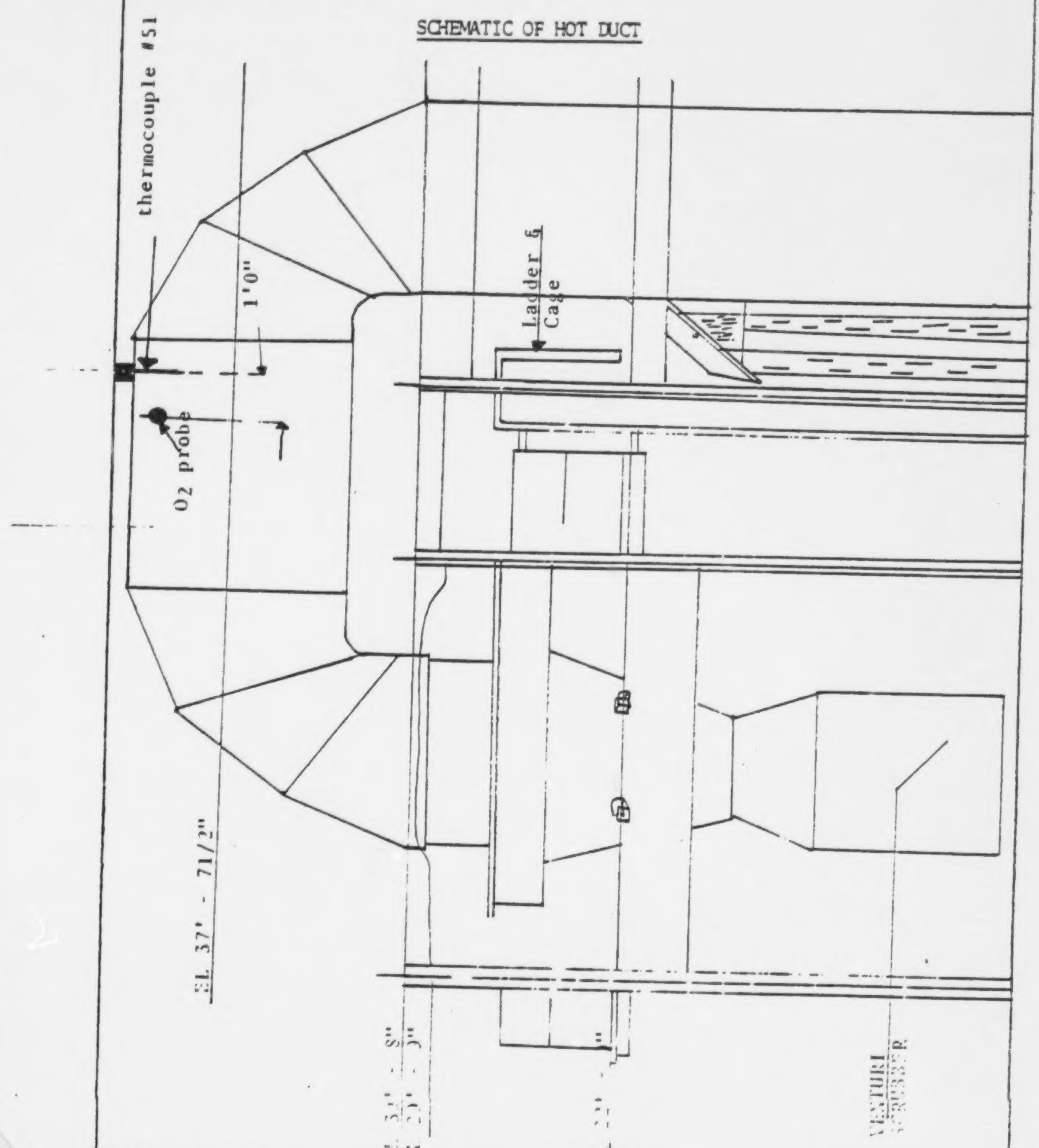
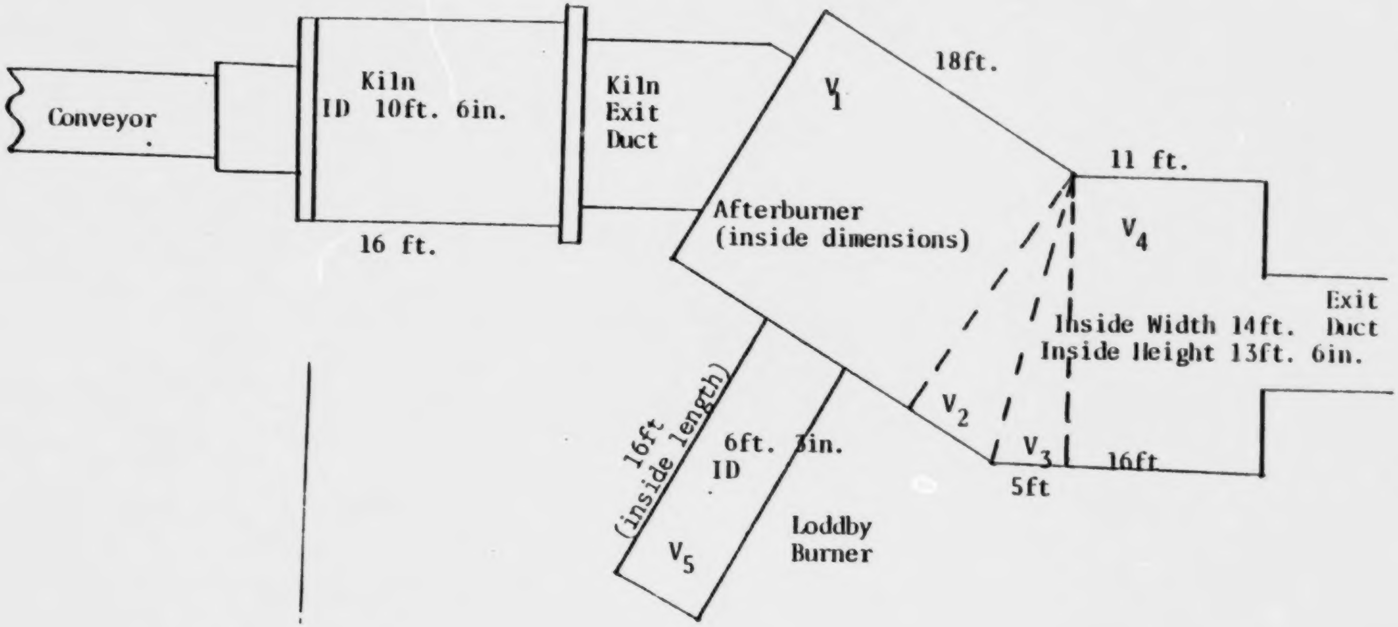


FIGURE 5

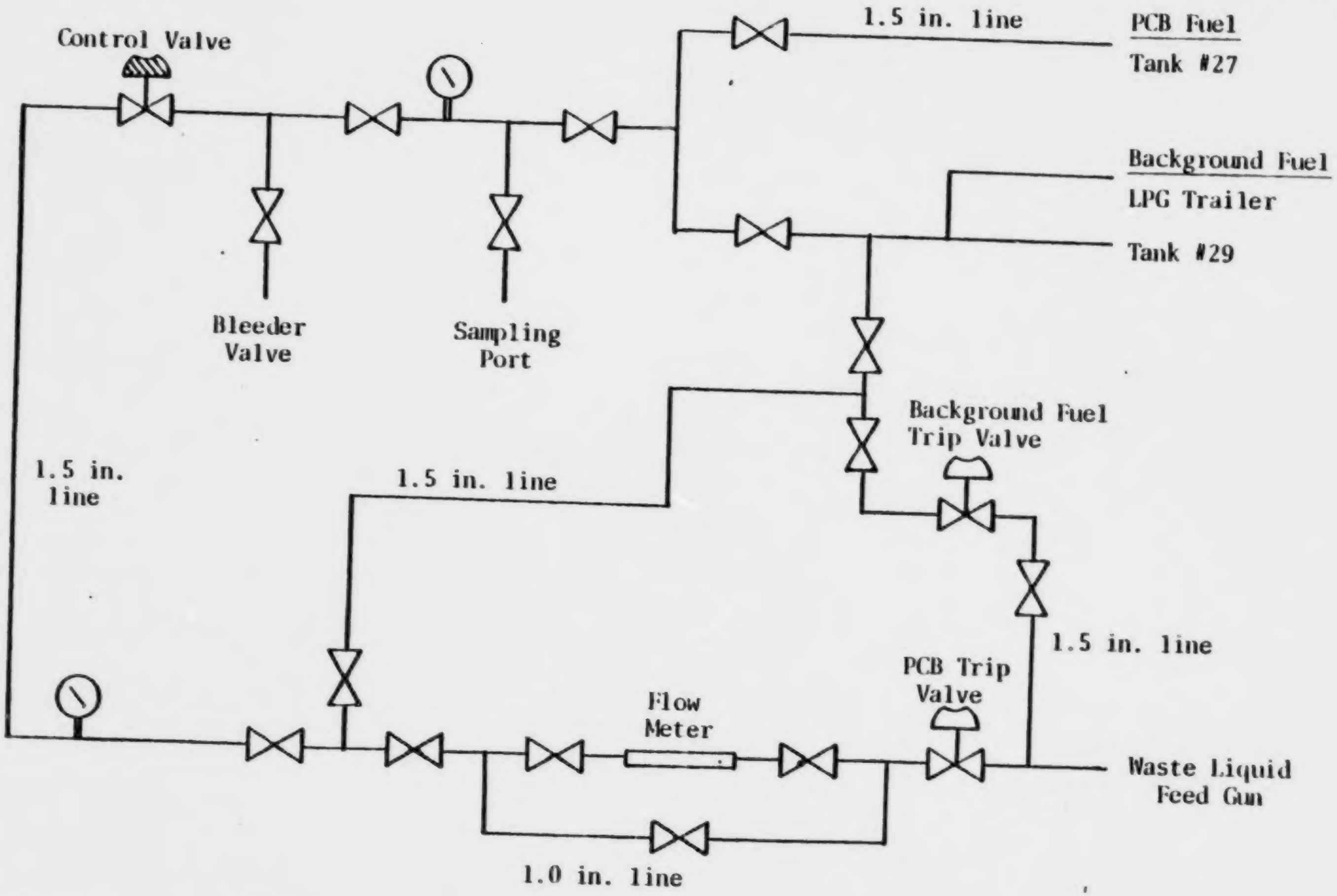
INCINERATION SYSTEM - PLAN VIEW



## FIGURE 6

## PCB FEED PIPING LAYOUT DURING PCB INCINERATION TEST

November 12-15, 1979



## FIGURE 7

## SCHEMATIC OF CARBON MONOXIDE AND LOW TEMPERATURE AUTOMATIC CUT- OFFS

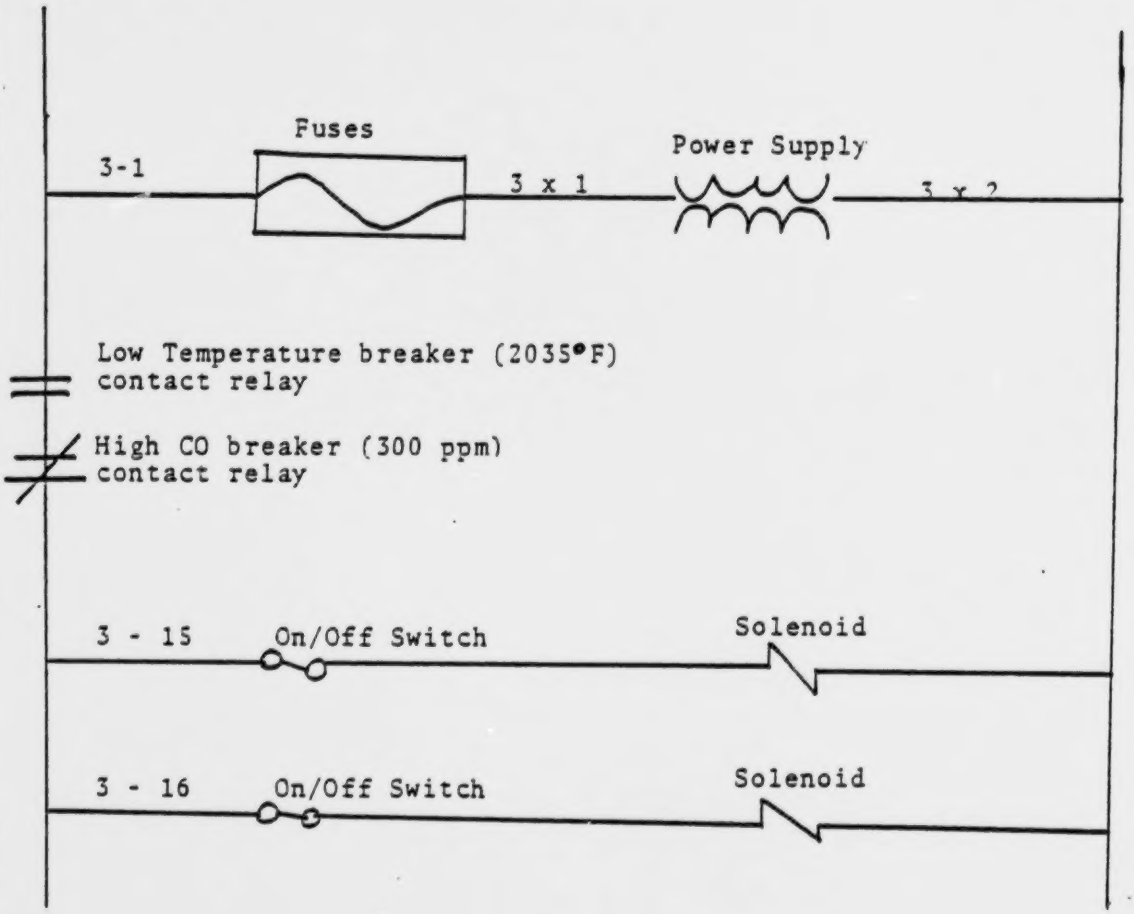


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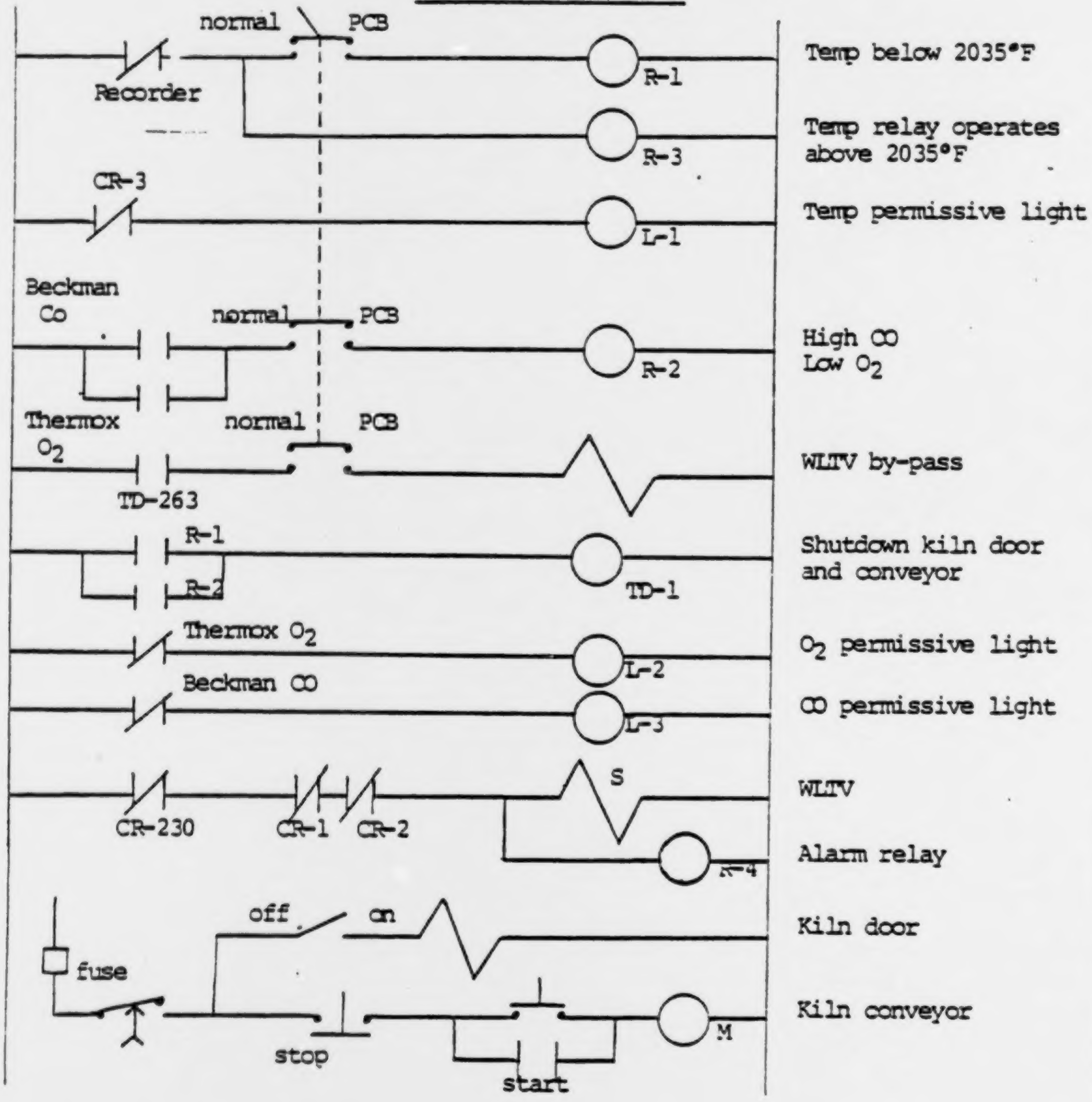
FIGURE 8

CONTROL CIRCUITRY FOR PCB INCINERATION TEST
November 12-15, 1979



| | |
|---|---|
| WLTV | waste liquid trip valve |
| TD | time delay relay |
| CR | control relay |
| M | motor contacter |
| R | relay |
| S | solenoid |
| L | light |

ALARM CONTACTS

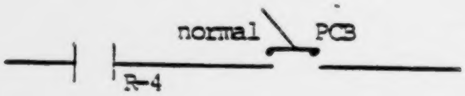
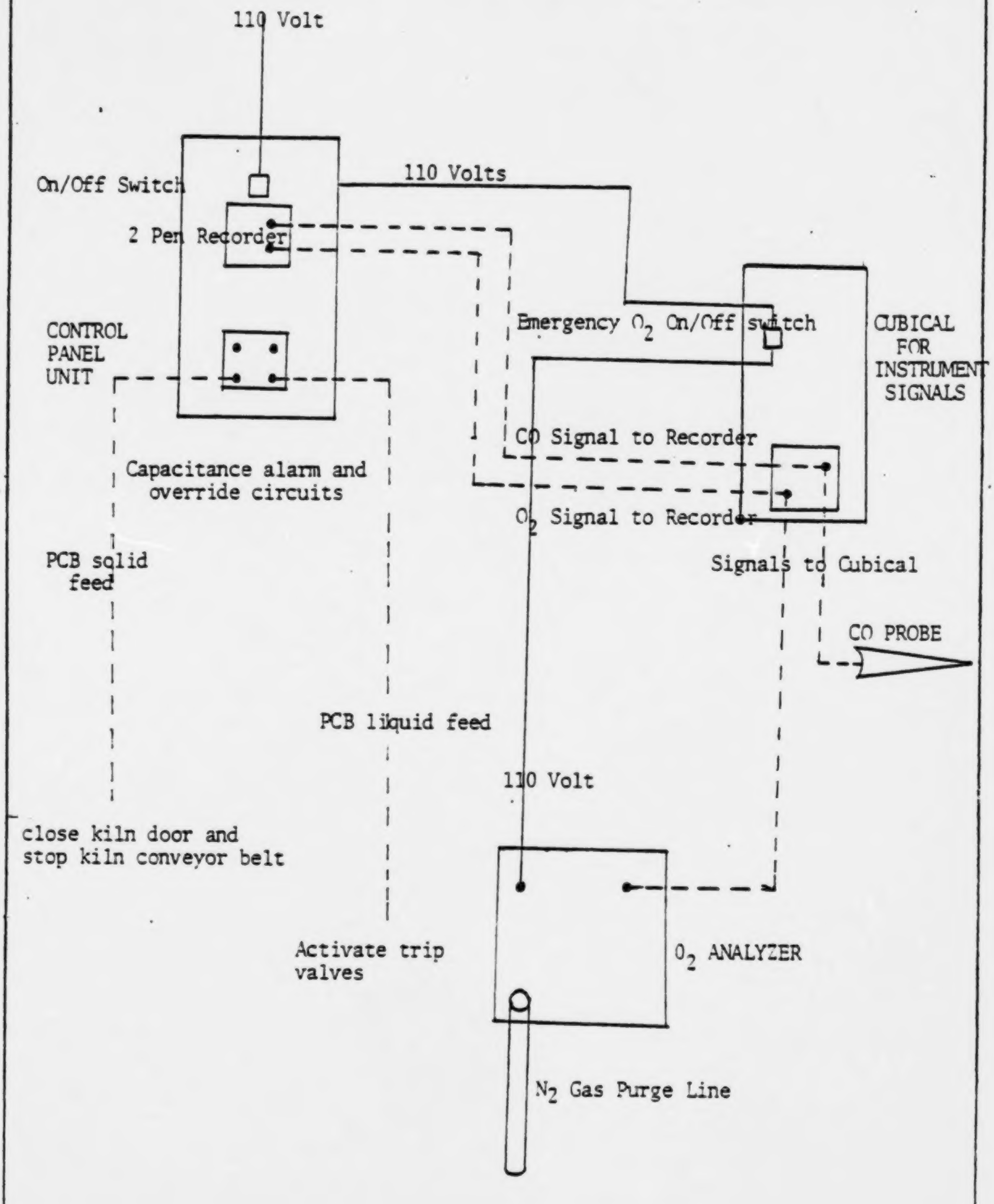


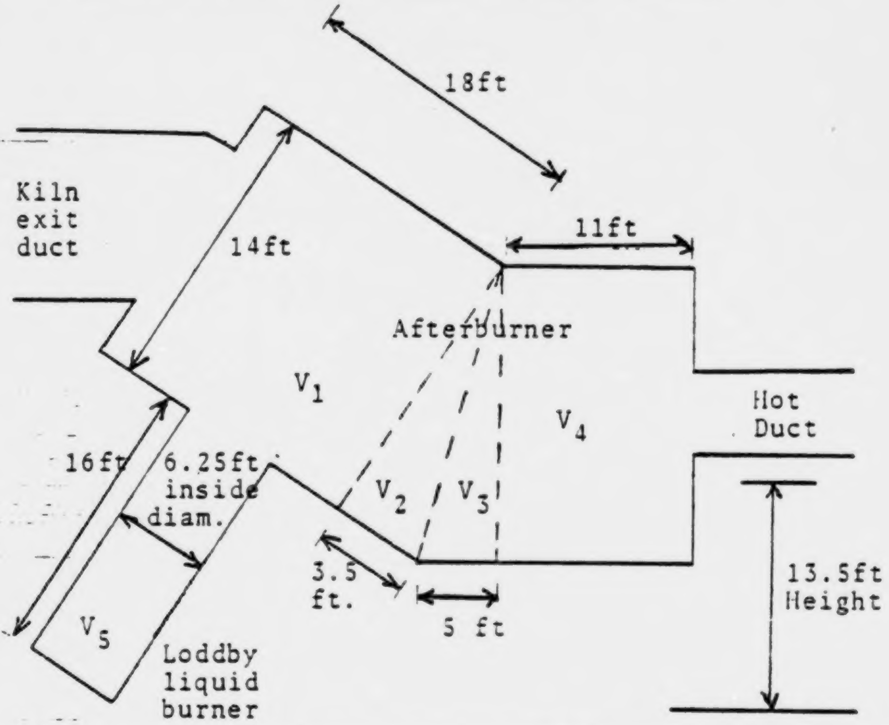
FIGURE 9

SCHEMATIC OF THE CARBON MONOXIDE AND OXYGEN CONTINUOUS ANALYZERS



## FIGURE 10

## VOLUME OF AFTERBURNER AND LODDBY BURNER IN THE INCINERATOR COMPLEX



**Afterburner**

$V_1$ = 18 x 14 x 13.5 = 3402

$V_2$ = {(3.5 x 14)/2} x 13.5 = 331

$V_3$ = {(5 x 14)/2} x 13.5 = 473

$V_4$ = 11 x 14 x 13.5 = 2079

6285 cu.ft.

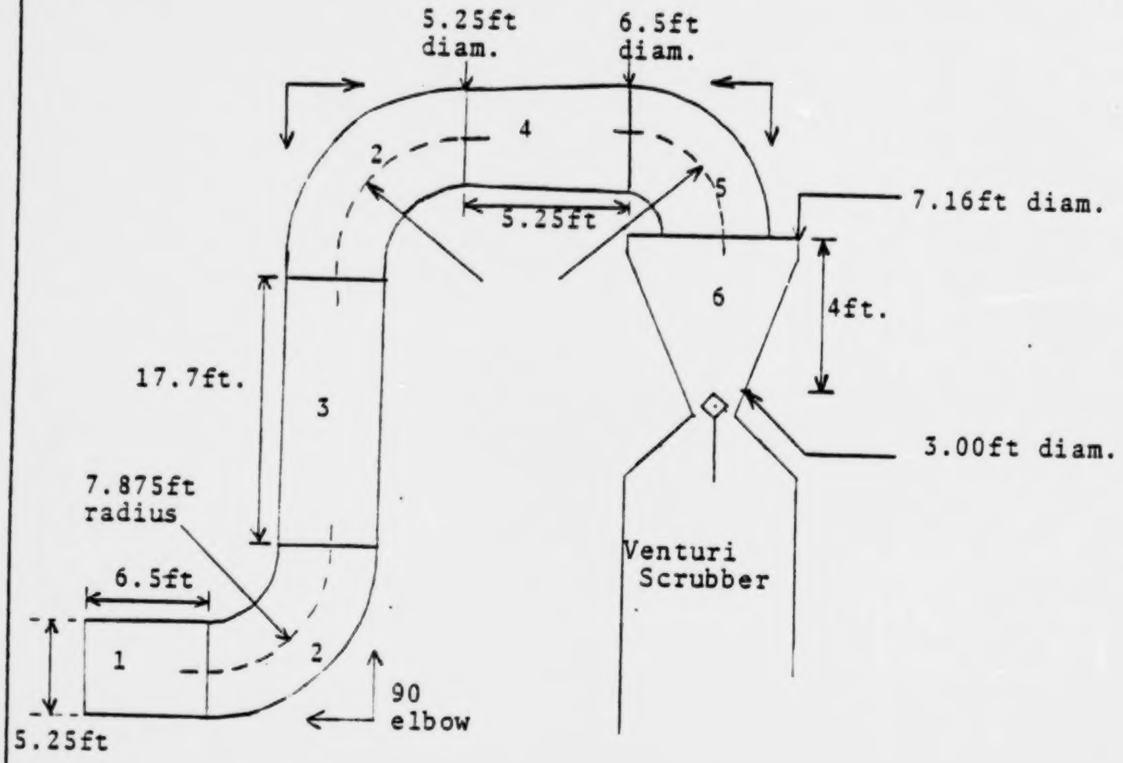
**Loddby**

$V_5$ = π x 9.77 x 16 = 491 cu.ft.

NOTE: All dimensions are inside.

## FIGURE 11

## VOLUME OF HOT DUCT IN THE INCINERATOR COMPLEX



$V_1 = \pi(2.625)^2(6.5) = 140.7$ 141

$V_2 = \pi(2.625)^2(7.875)(\pi/2) = 267.8$ 536

$V_3 = \pi(2.625)^2(17.7) = 383.2$ 383

$V_4 = \pi/3\{(2.625)^2 + (3.25)^2 + (72.78)^{\frac{1}{2}}\}(5.25) = 142.9$ 143

$V_5 = \pi(3.25)^2(7.875)(\pi/2) = 410.5$ 411

$V_6 = \pi/3\{(3.58)^2 + (1.50)^2 + (28.84)^{\frac{1}{2}}\}(4.00) = 85.6$ 86

1700 cu.ft.

NOTE: All dimensions are internal.

~~APPROXIMATE COMPOSITE~~

Buffalo

Buffalo Forge Co

PERFORMANCE CURVES

Buffalo, N Y

For ROLLINS PURLE

Size 980 Type H-36 1780 rpm, 120 °F. ____ Hg; .0472 lb. cu ft

PC 4535

Ord No 72P-14776

Sl No ____

Date 12-26-72

By JAK

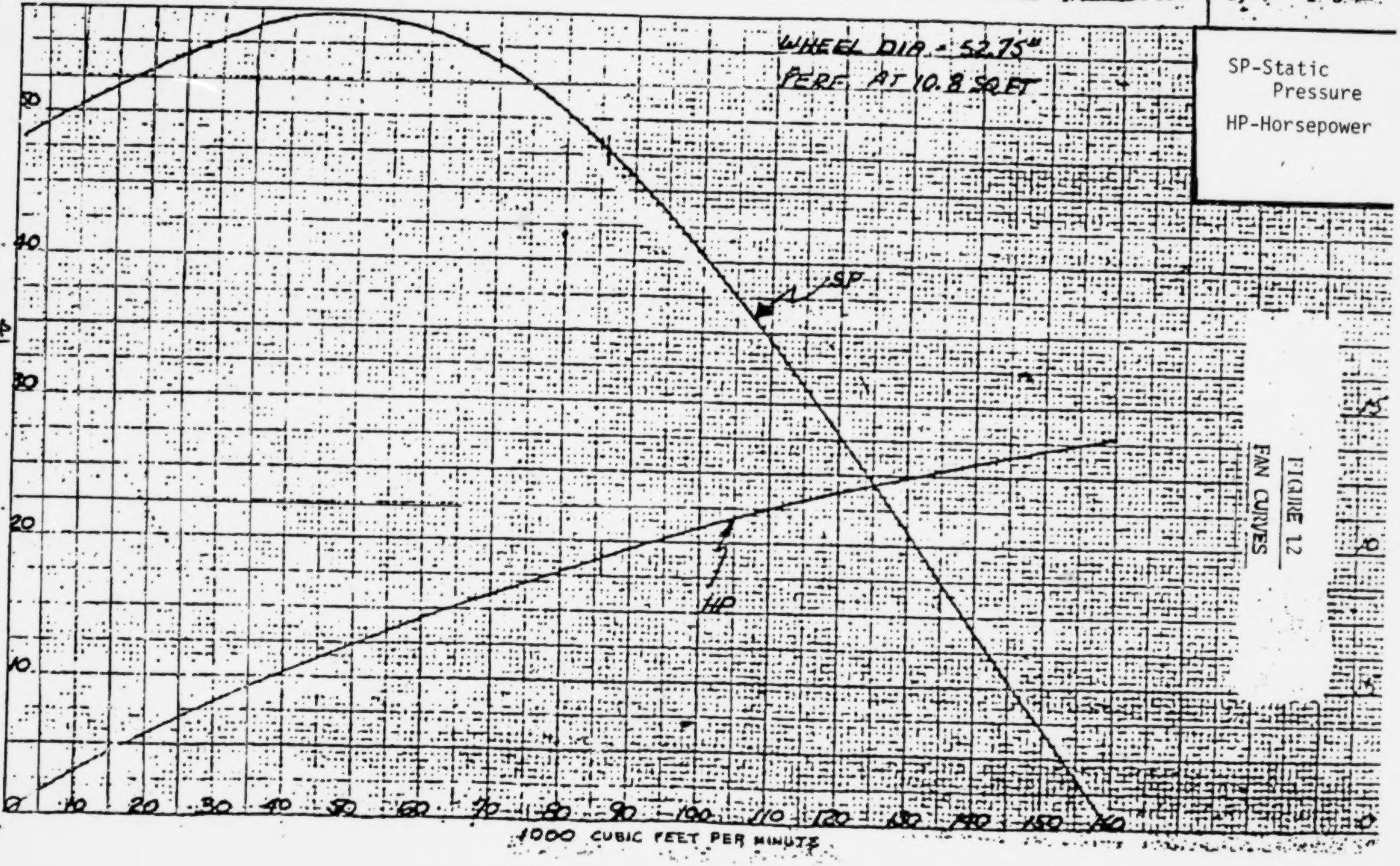


FIGURE 12

FAN CURVES

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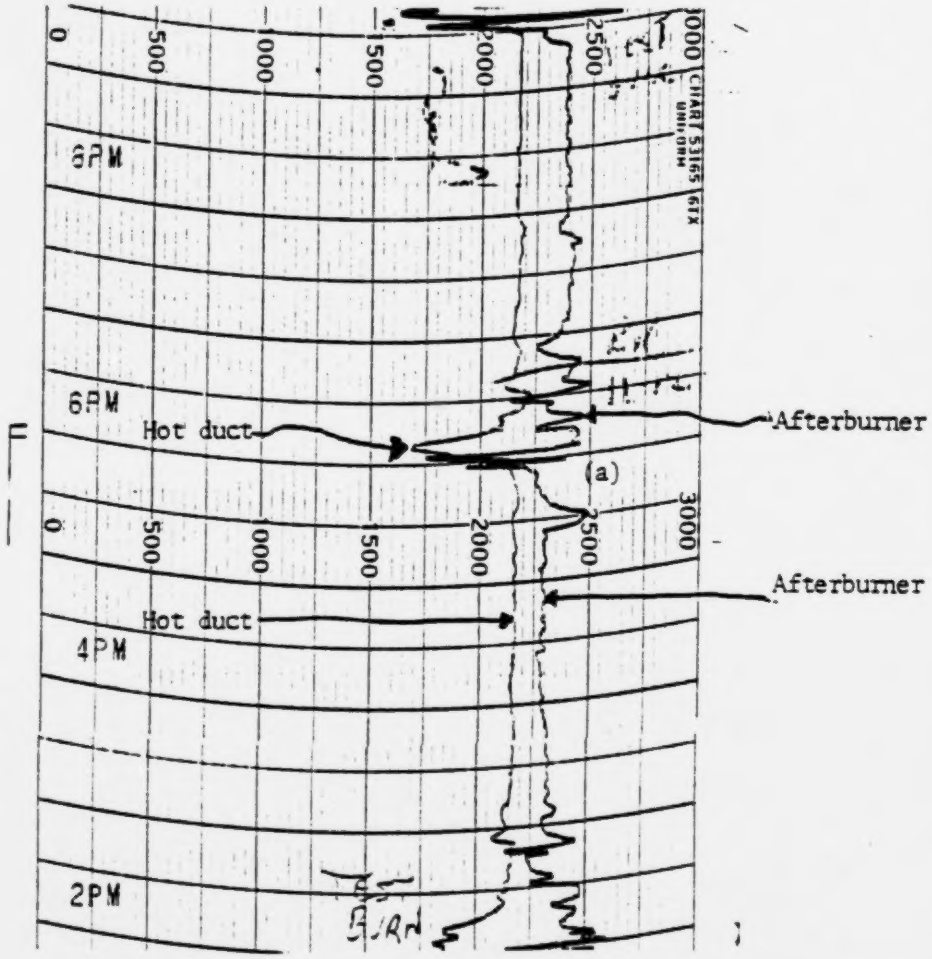
## FIGURE 13

## AFTERBURNER AND HOT DUCT TEMPERATURES DURING PCB INCINERATION TEST

Run 1 incineration of background fuel

November 12, 1979 from 1400 to 2045 hrs.

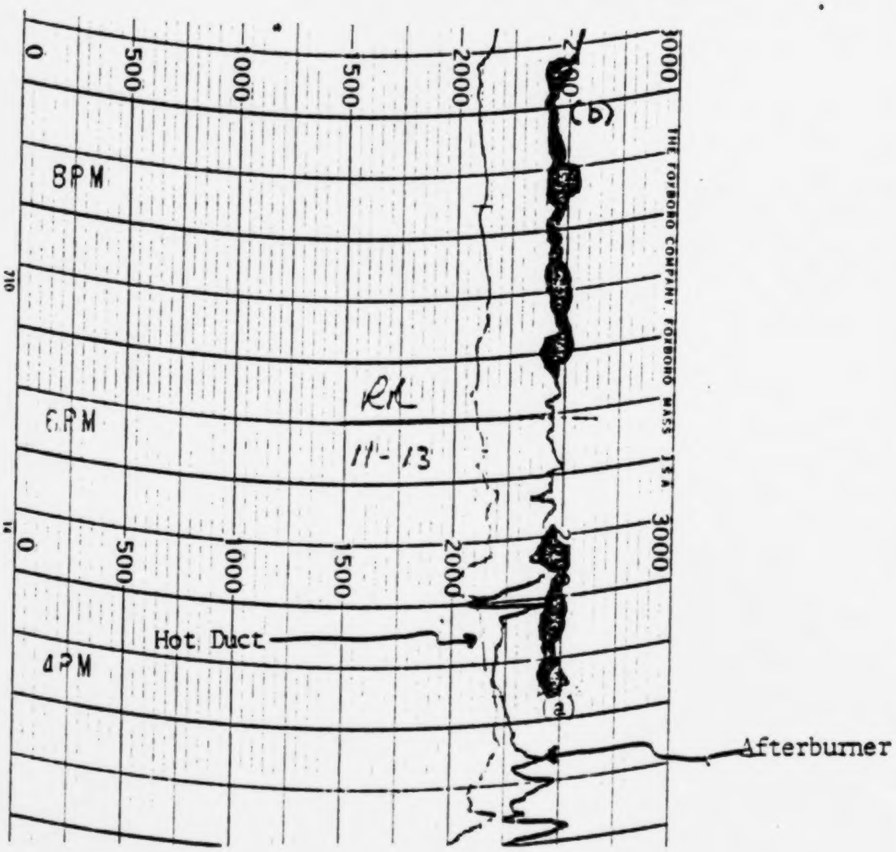


(a). Feed line plugged, causing temperature decrease which activated shut-down at .

FIGURE 13 (cont'd)

AFTERBURNER AND HOT DUCT TEMPERATURES DURING
PCB INCINERATION TEST

Run 2 incineration of PCB fuel
November 13, 1979 from 1430 to 2115 hrs.



(a). PCB stack sampling train plugged at 1605 hrs. and PCB feed was shut-off. Problem was corrected and PCB feed was started at 1625 hrs.

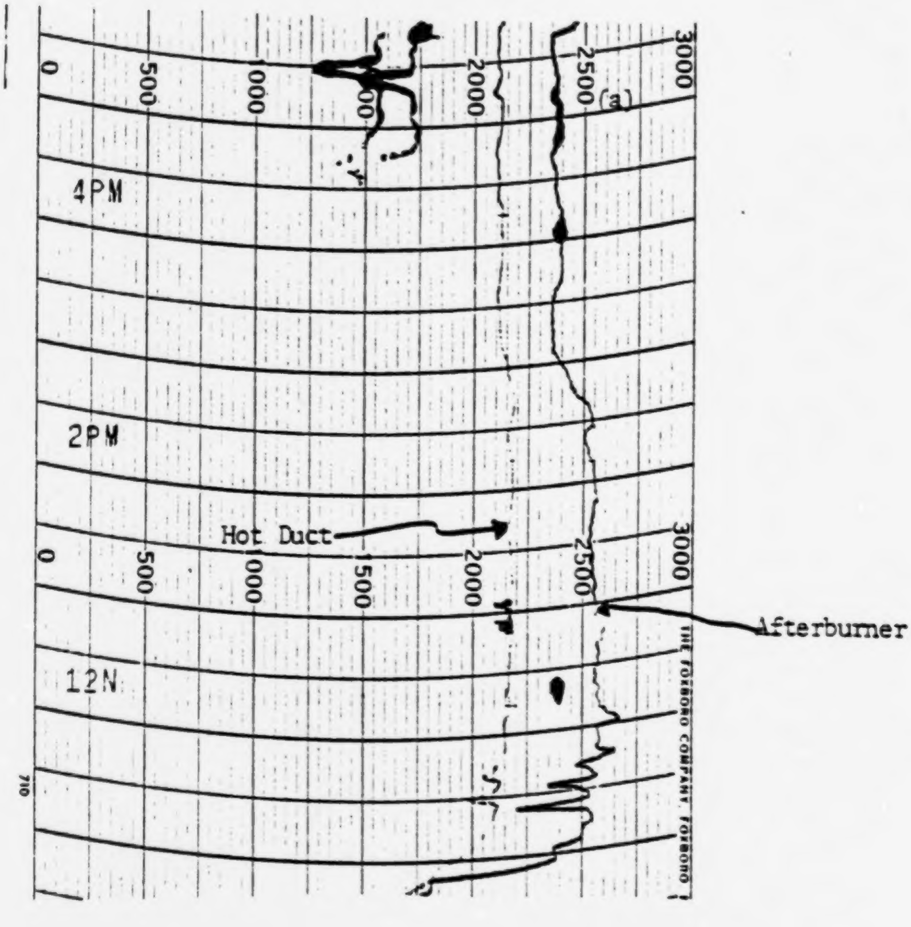
(b). Shut off PCB feed at 2050 hrs. and purged system for 0.5 hr. with background fuel.

## FIGURE 13 (cont'd)

## AFTERBURNER AND HOT DUCT TEMPERATURES DURING PCB INCINERATION TEST

Run 3 incineration of PCB fuel

November 14, 1979 from 1045 to 1730 hrs.



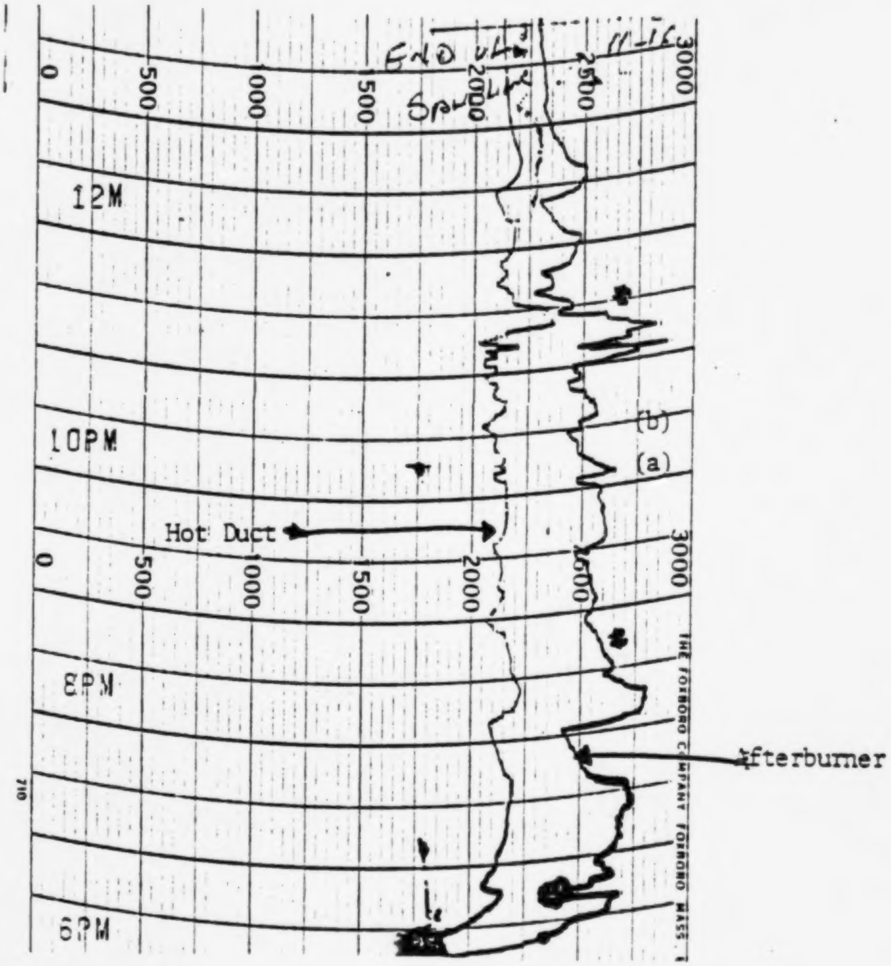
(a). Shut off PCB feed at 1708 hrs. and purged system for 0.5 hr with background fuel.

## FIGURE 13 (cont'd)

## AFTERBURNER AND HOT DUCT TEMPERATURES DURING PCB INCINERATION TEST

Run 4 incineration of PCB fuel

November 15 - 16, 1979 from 1800 to 0100 hrs.



(a). Plug in kiln feed line: shut off PCB feed at 2212 hrs.

(b). Problem corrected and PCB feed resumed at 2227 hrs.

FIGURE 13 (cont'd)

AFTERBURNER AND HOT DUCT TEMPERATURES DURING PCB INCINERATION TEST

Burn-out of excess PCB fuel
November 16, 1979 from 0108 to 0335 hrs.

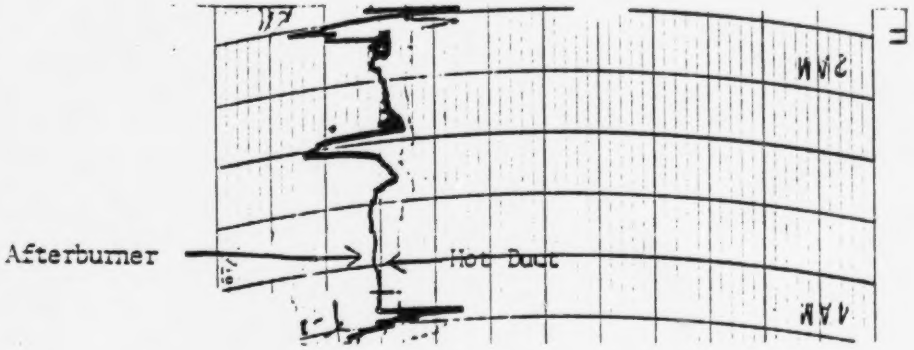
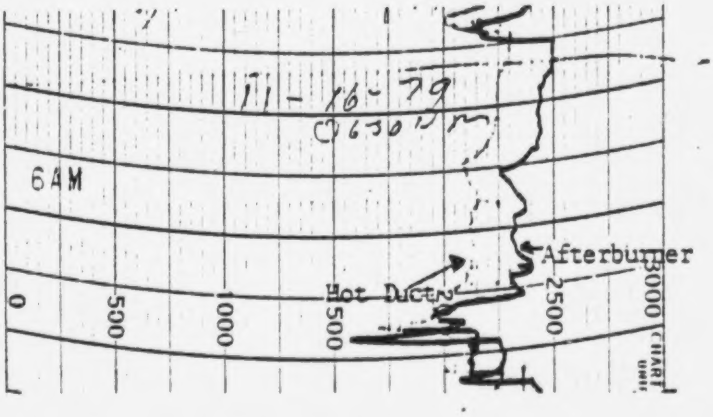


FIGURE 13 (cont'd)

AFTERBURNER AND HOT DUCT TEMPERATURES DURING
PCB INCINERATION TEST

Incineration of First Flush
November 16, 1979 from 0430 to 0730 hrs.



## FIGURE 13 (cont'd)

## AFTERBURNER AND HOT DUCT TEMPERATURES DURING PCB INCINERATION TEST

Incineration of Second Flush
November 16, 1979 from 0930 to 1215 hrs.

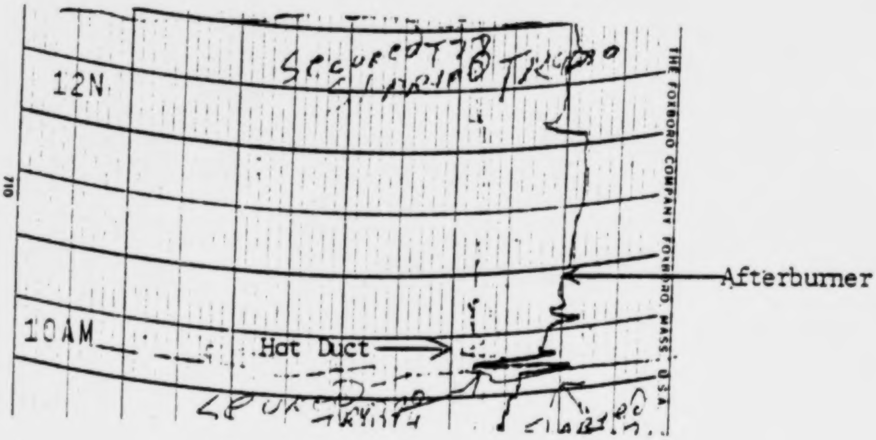


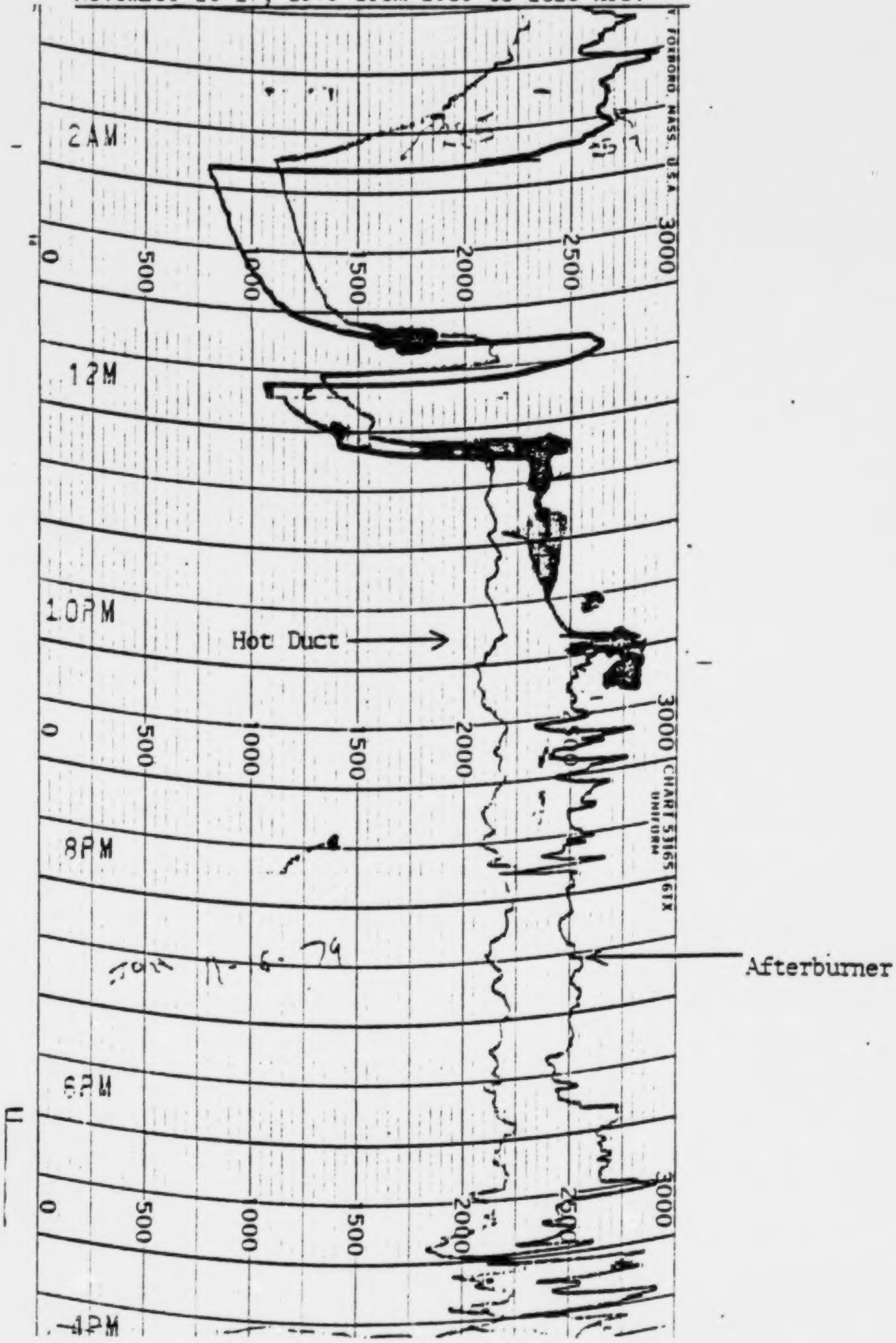
FIGURE 13 (cont'd)

AFTERBURNER AND HOT DUCT TEMPERATURES DURING

PCB INCINERATION TEST

Incineration of Third Flush

November 16-17, 1979 from 1630 to 1315 hrs.



(cont'd)

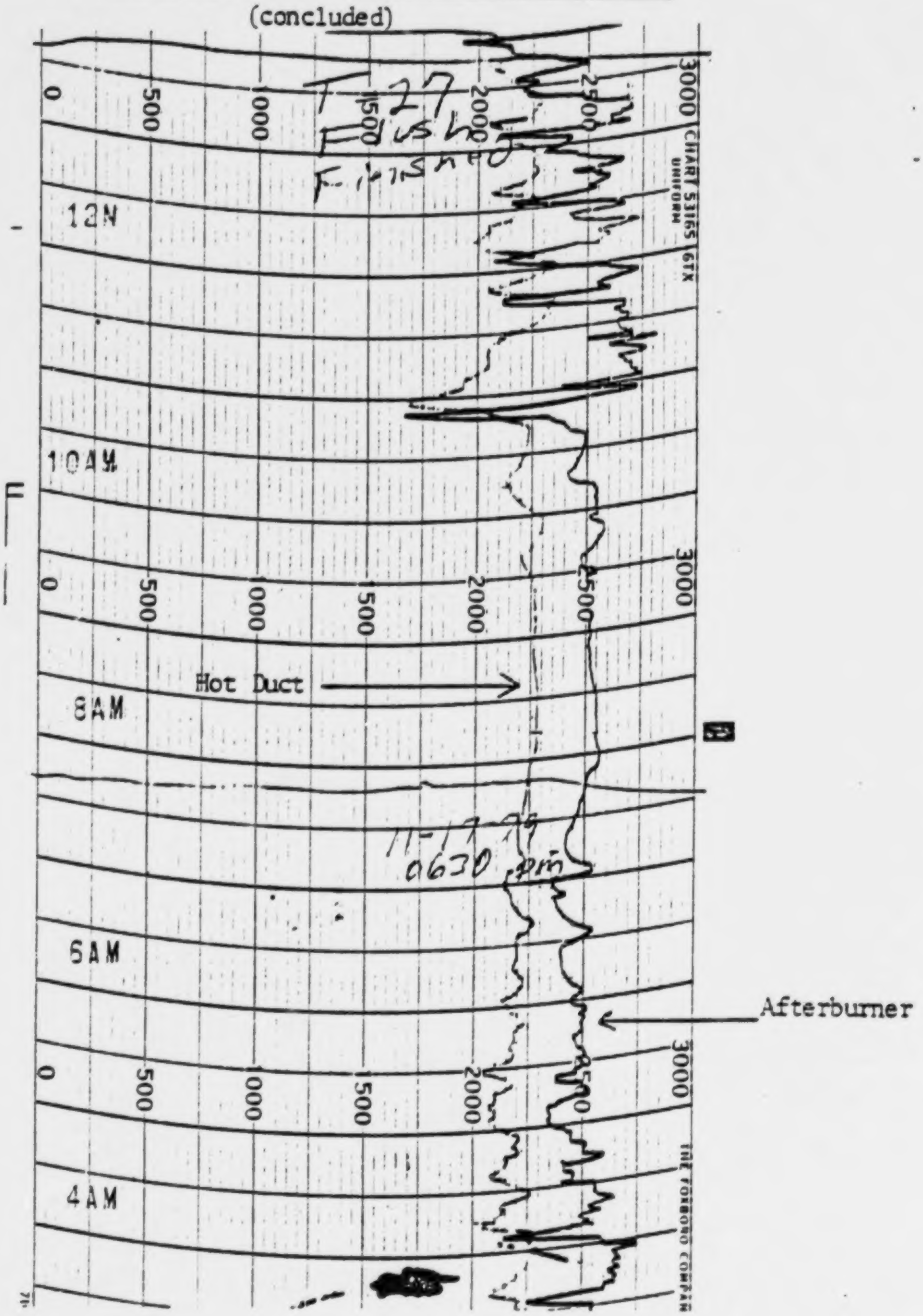
## FIGURE 13 (cont'd)

## AFTERBURNER AND HOT DUCT TEMPERATURES DURING PCB INCINERATION TEST

Incineration of Third Flush

November 16-17, 1979 from 1630 to 1315 hrs.

(concluded)

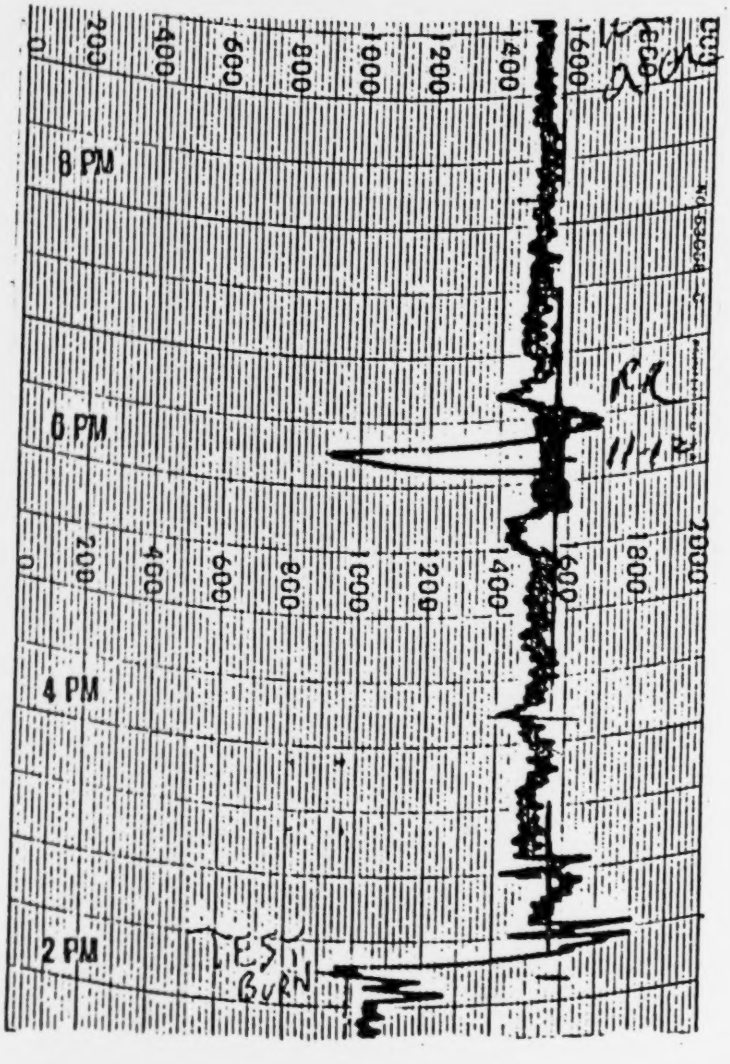


### FIGURE 14

### KILN TEMPERATURES DURING PCB INCINERATION TEST

Run 1 incineration of background fuel

November 12, 1979 from 1400 to 2045 hrs.

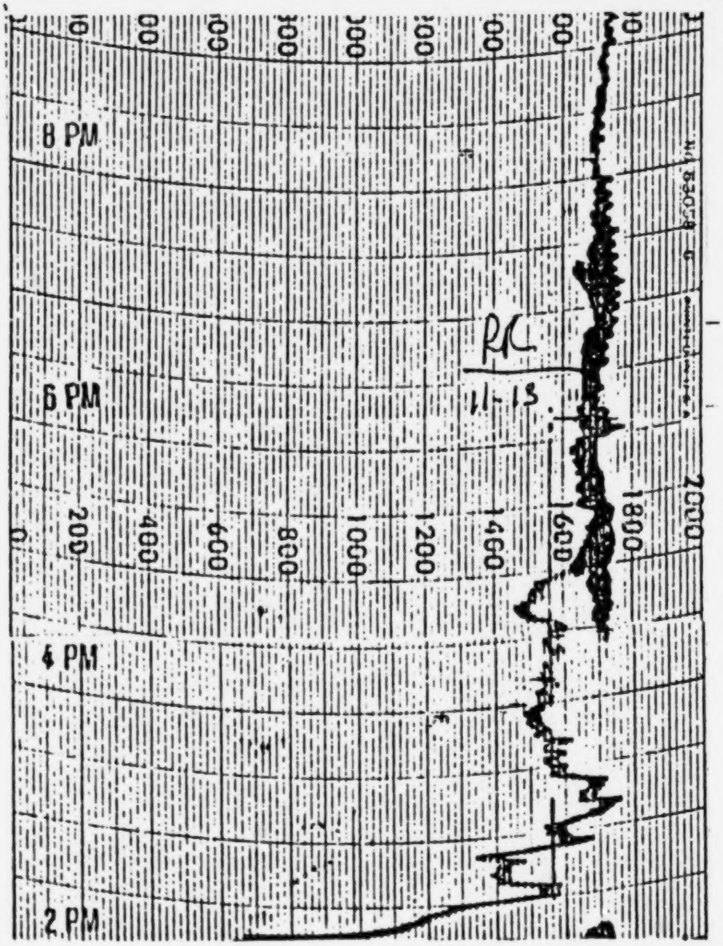


## FIGURE 14 (cont'd)

## KILN TEMPERATURE DURING PCB INCINERATION TEST

Run 2 incineration of PCB fuel

November 13, 1979 from 1430 to 2115 hrs.



## FIGURE 14 (cont'd)

## KILN TEMPERATURE DURING PCB INCINERATION TEST

Run 3 incineration of PCB fuel

November 14, 1979 from 1045 to 1730 hrs.

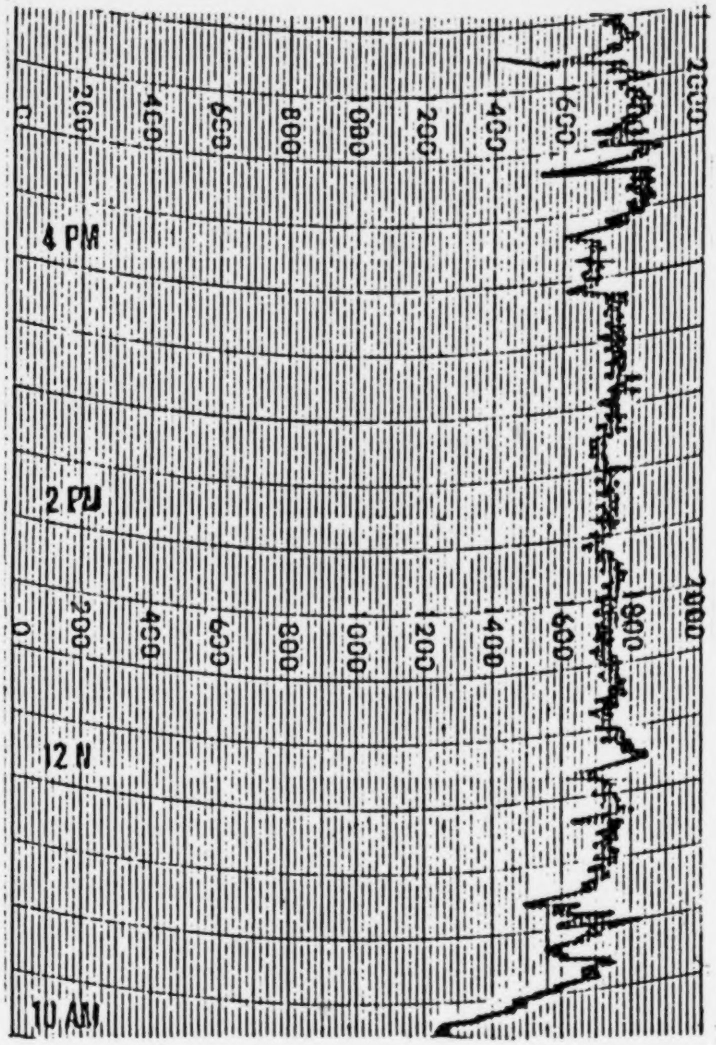
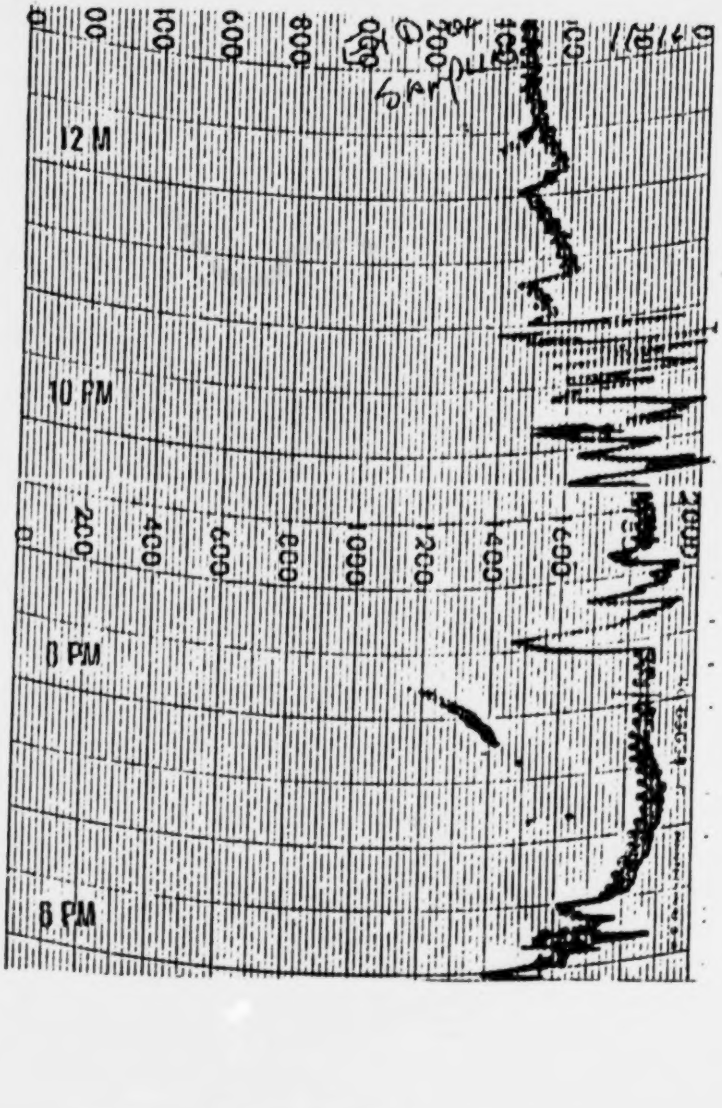


FIGURE 14 (cont'd)

KILN TEMPERATURE DURING PCB INCINERATION TEST

Run 4 incineration of PCB fuel
November 15-16, 1979 from 1800 to 0100 hrs.

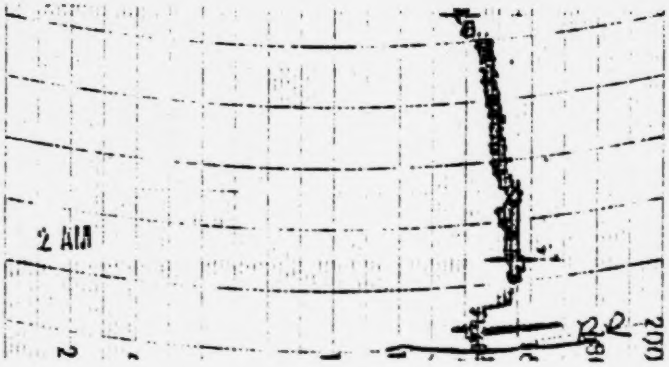


## FIGURE 14 (cont'd)

## KILN TEMPERATURE DURING PCB INCINERATION TEST

Burn-out of excess PCB fuel

November 16, 1979 from 0108 to 0335 hrs.

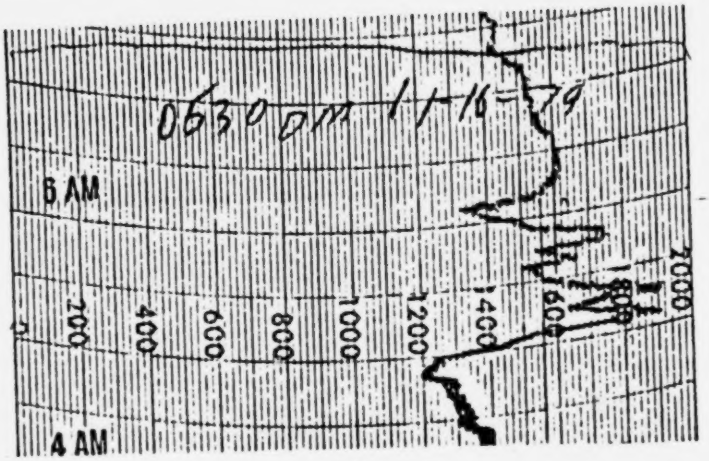


## FIGURE 14 (cont'd)

## KILN TEMPERATURE DURING PCB INCINERATION TEST

Incineration of First Flush

November 16, 1979 from 0430 to 0730 hrs.

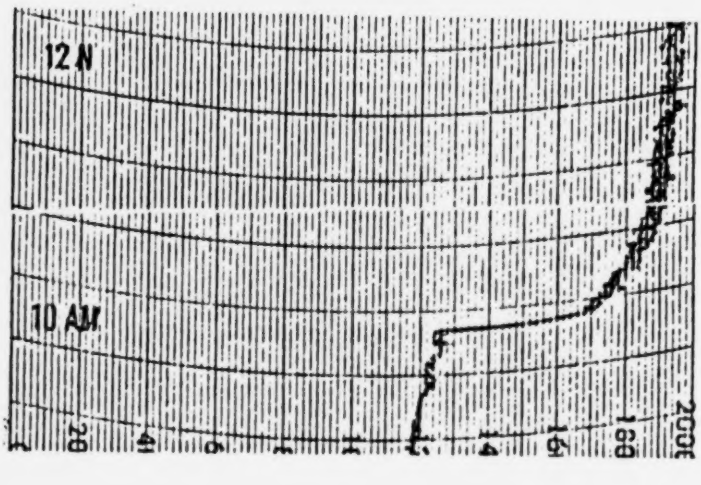


## FIGURE 14 (cont'd)

## KILN TEMPERATURE DURING PCB INCINERATION TEST

### Incineration of Second Flush

### November 16, 1979 from 0930 to 1215 hrs.

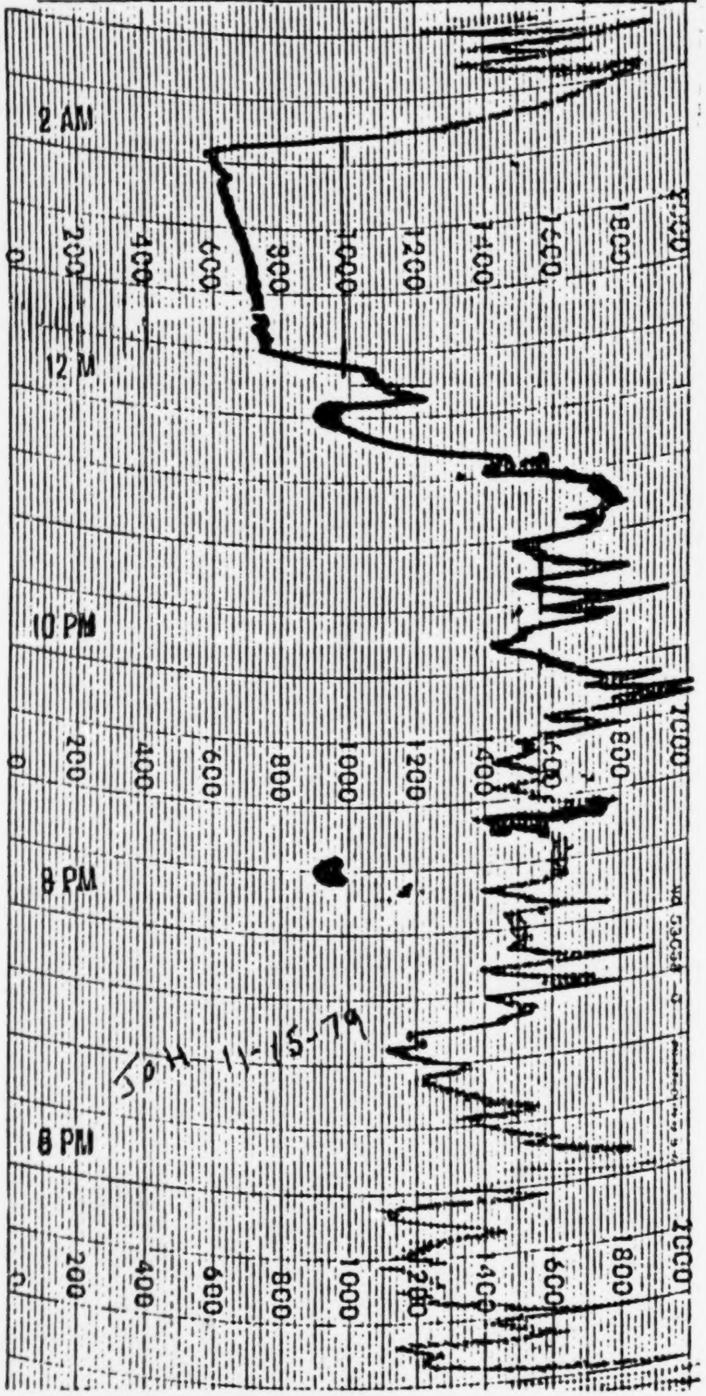


## FIGURE 14 (cont'd)

## KILN TEMPERATURE DURING PCB INCINERATION TEST

### Incineration of Third Flush

November 16-17, 1979 from 1630 to 1315 hrs.



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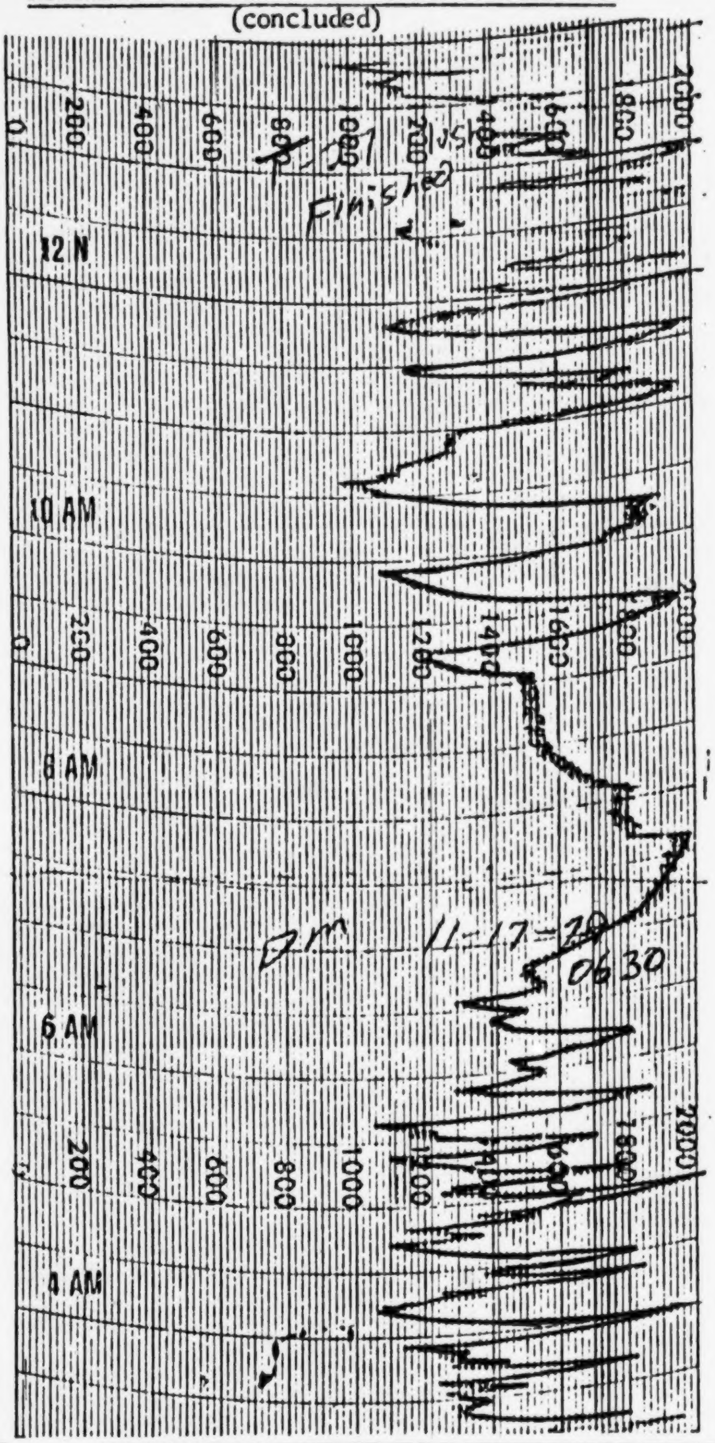
## FIGURE 14 (cont'd)

## KILN TEMPERATURE DURING PCB INCINERATION TEST

Incineration of Third Flush

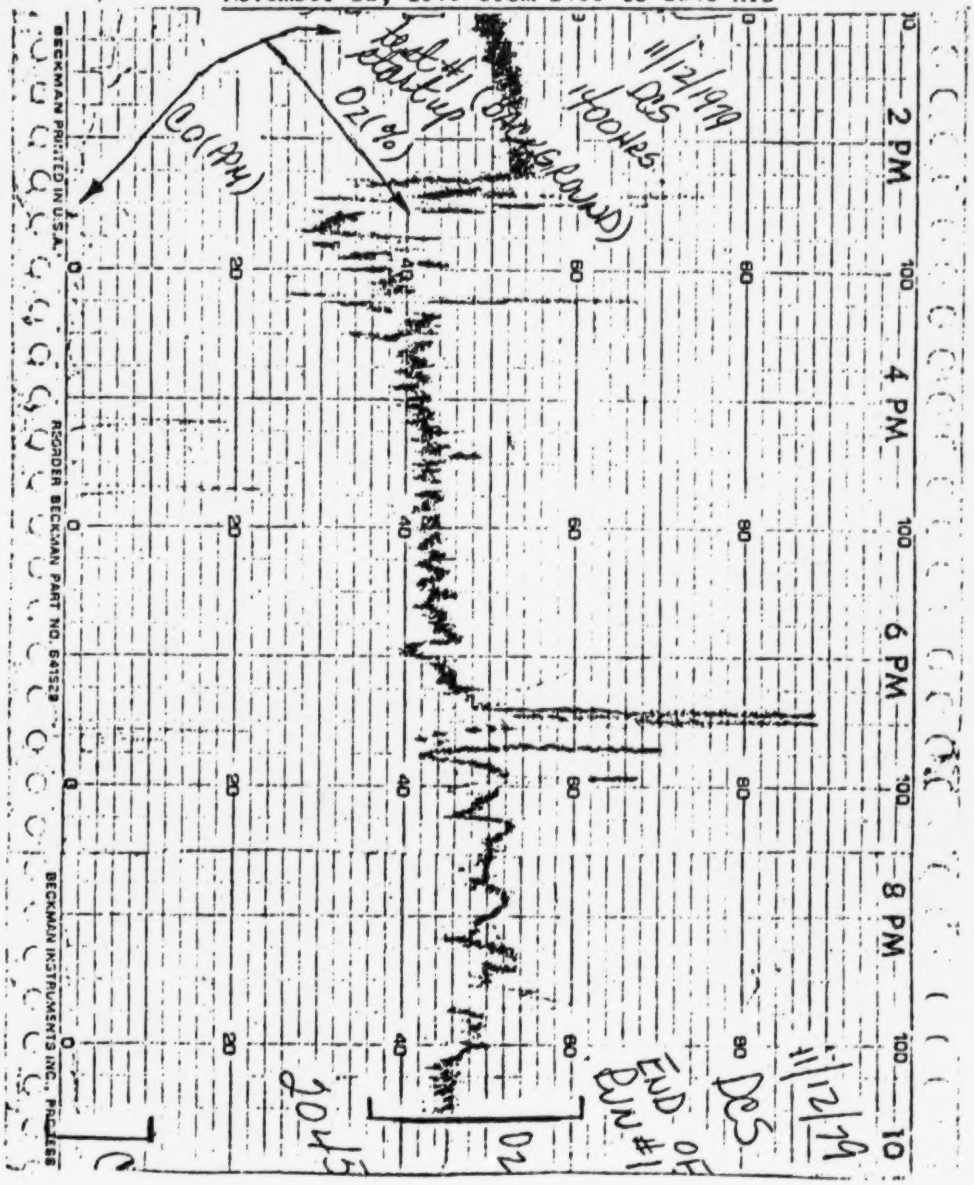
November 16-17 1979 from 1630 to 1315 hrs.
(concluded)



## FIGURE 15

CARBON MONOXIDE AND OXYGEN CONCENTRATIONS DURING THE PCB INCINERATION TEST

Run 1 incineration of background fuel
November 12, 1979 from 1400 to 2045 hrs

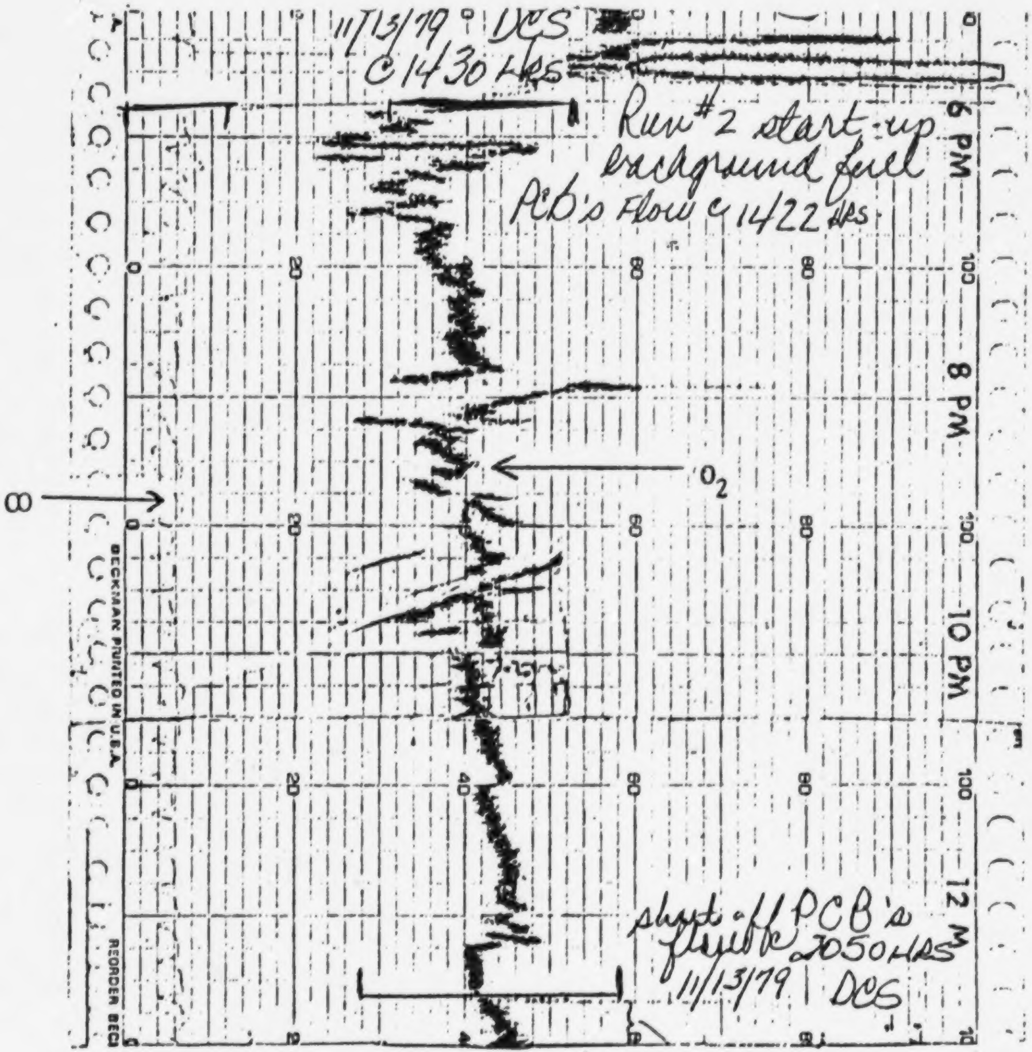


## FIGURE 15 (cont'd)

## CARBON MONOXIDE AND OXYGEN CONCENTRATIONS DURING THE PCB INCINERATION TEST

Run 2 incineration of PCB fuel

November 13, 1979 from 1430 to 2115 hrs.



11/13/79 @ DCS
@ 1430 Hrs

Run #2 start-up
background fuel
PCB's Flow @ 1422 Hrs.

O$_2$

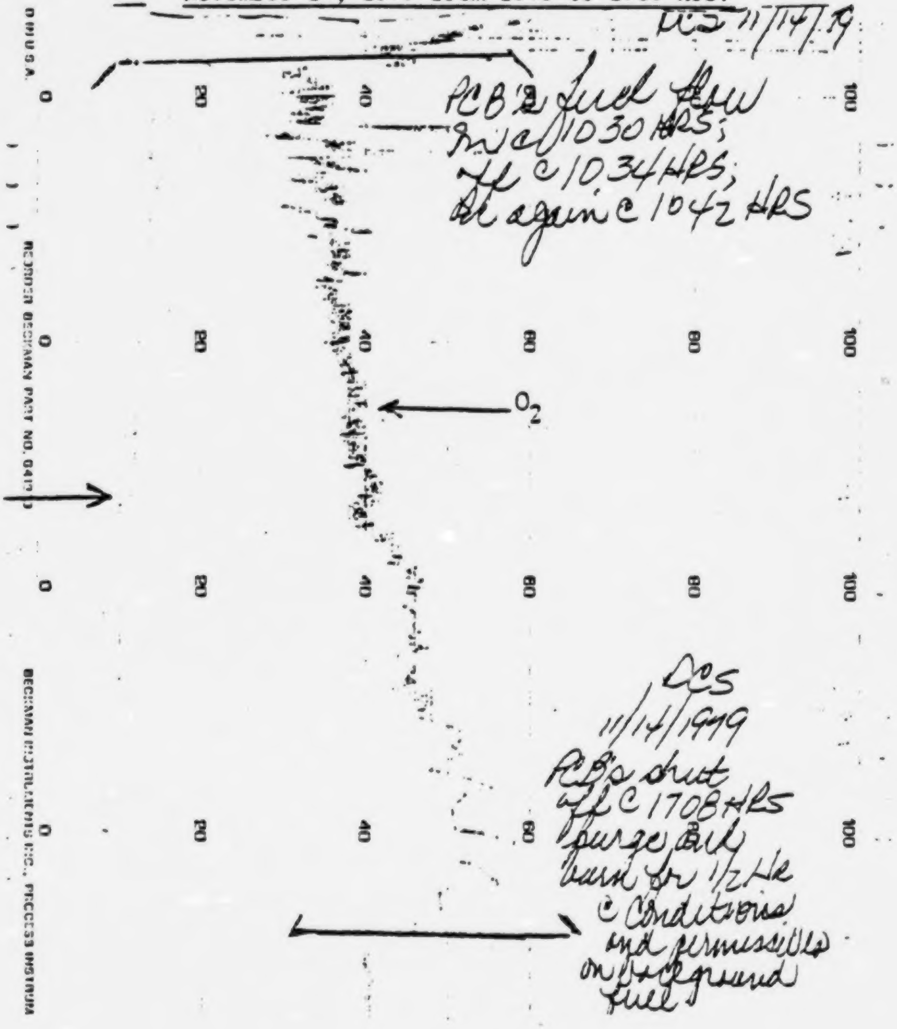
CO

shut off PCB's
flow @ 2050 Hrs
11/13/79 DCS

## FIGURE 15 (cont'd)

## CARBON MONOXIDE AND OXYGEN CONCENTRATION
## DURING THE PCB INCINERATION TEST

Run 3 incineration of PCB fuel
November 14, 1979 from 1045 to 1730 hrs.



DCS 11/14/79

PCB's fuel flow
in @ 1030 HRS;
off @ 1034 HRS;
on again @ 1042 HRS

DCS
11/14/1979
PCB's shut
off @ 1708 HRS
purge air
burn for 1/2 Hr
@ conditions
and permissibles
on background
fuel

FIGURE 15 (cont'd)

CARBON MONOXIDE AND OXYGEN CONCENTRATIONS DURING THE PCB INCINERATION TEST

Run 4 incineration of PCB fuel

November 15-16, 1979 from 1800 to 0100 hrs.

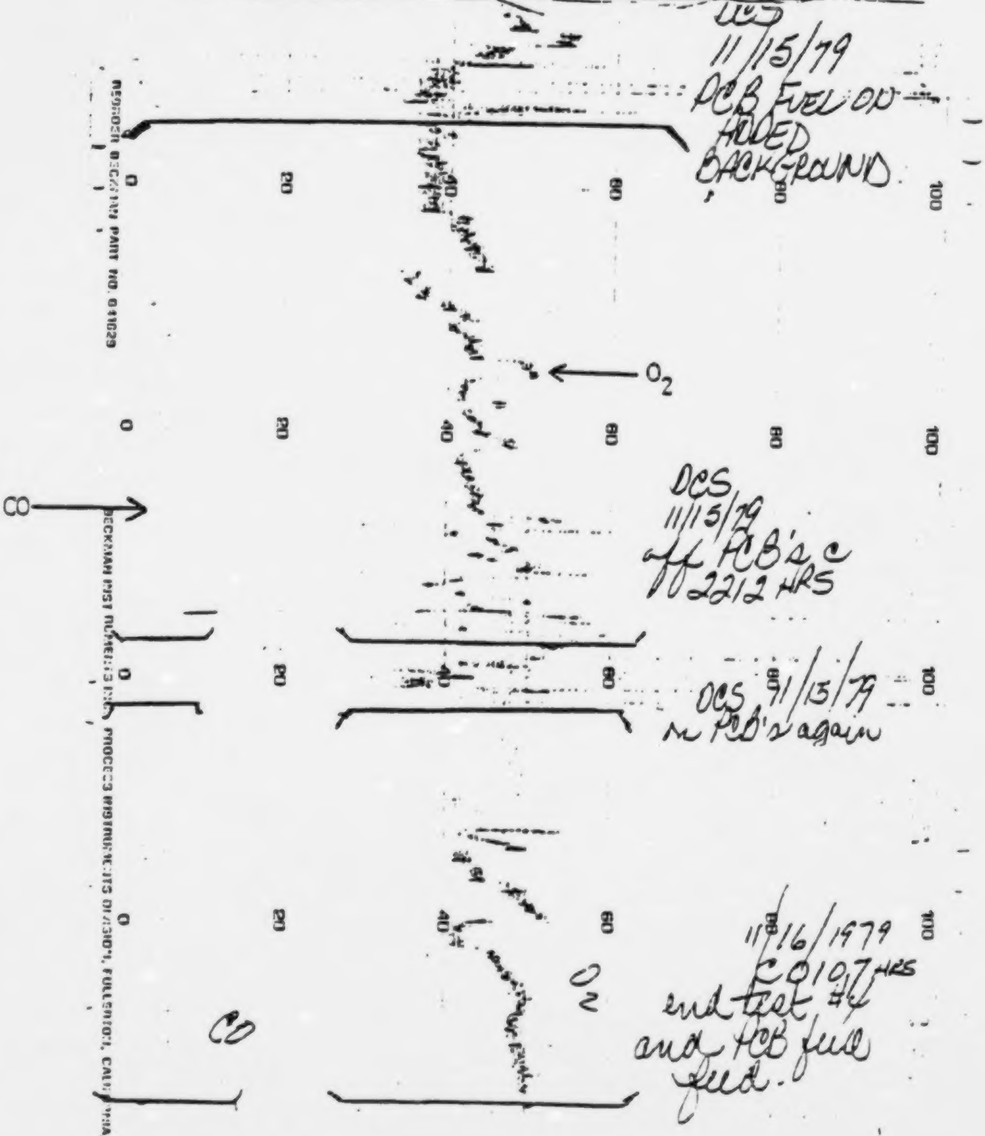
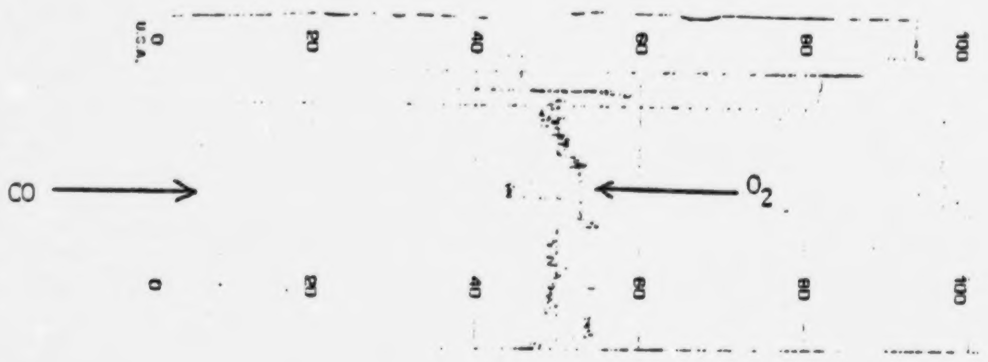


FIGURE 15 (cont'd)

CARBON MONOXIDE AND OXYGEN CONCENTRATIONS DURING THE PCB INCINERATION TEST

Burn-out of excess PCB fuel

November 16, 1979 from 0108 to 0335 hrs.

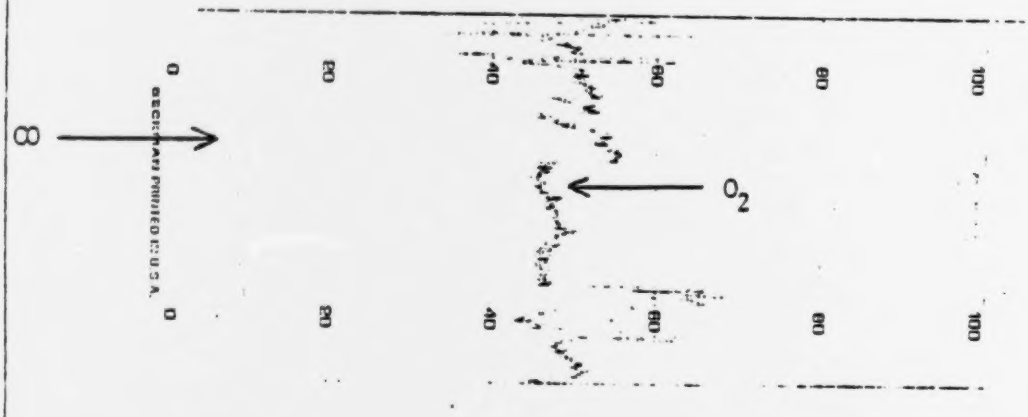


## FIGURE 15 (cont'd)

## CARBON MONOXIDE AND OXYGEN CONCENTRATIONS DURING THE PCB INCINERATION TEST

Incineration of First Flush

November 16, 1979 from 0430 to 0730 hrs.

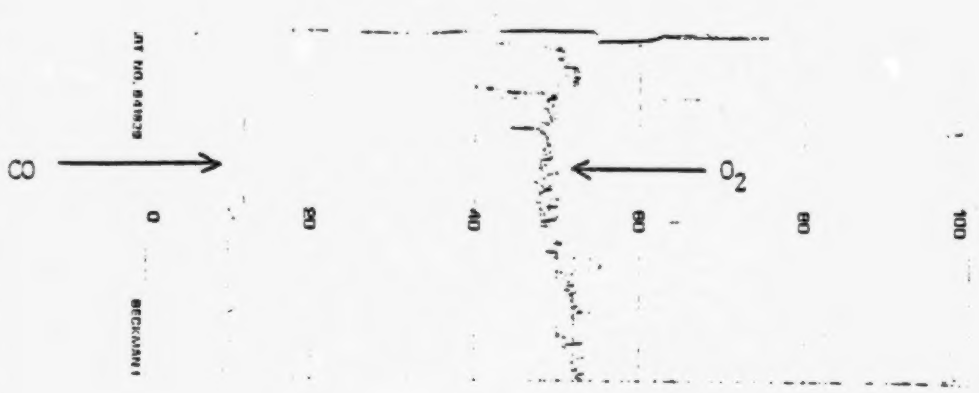


## FIGURE 15 (cont'd)

## CARBON MONOXIDE AND OXYGEN CONCENTRATIONS DURING THE PCB INCINERATION TEST

Incineration of Second Flush

November 16, 1979 from 0930 to 1215 hrs.

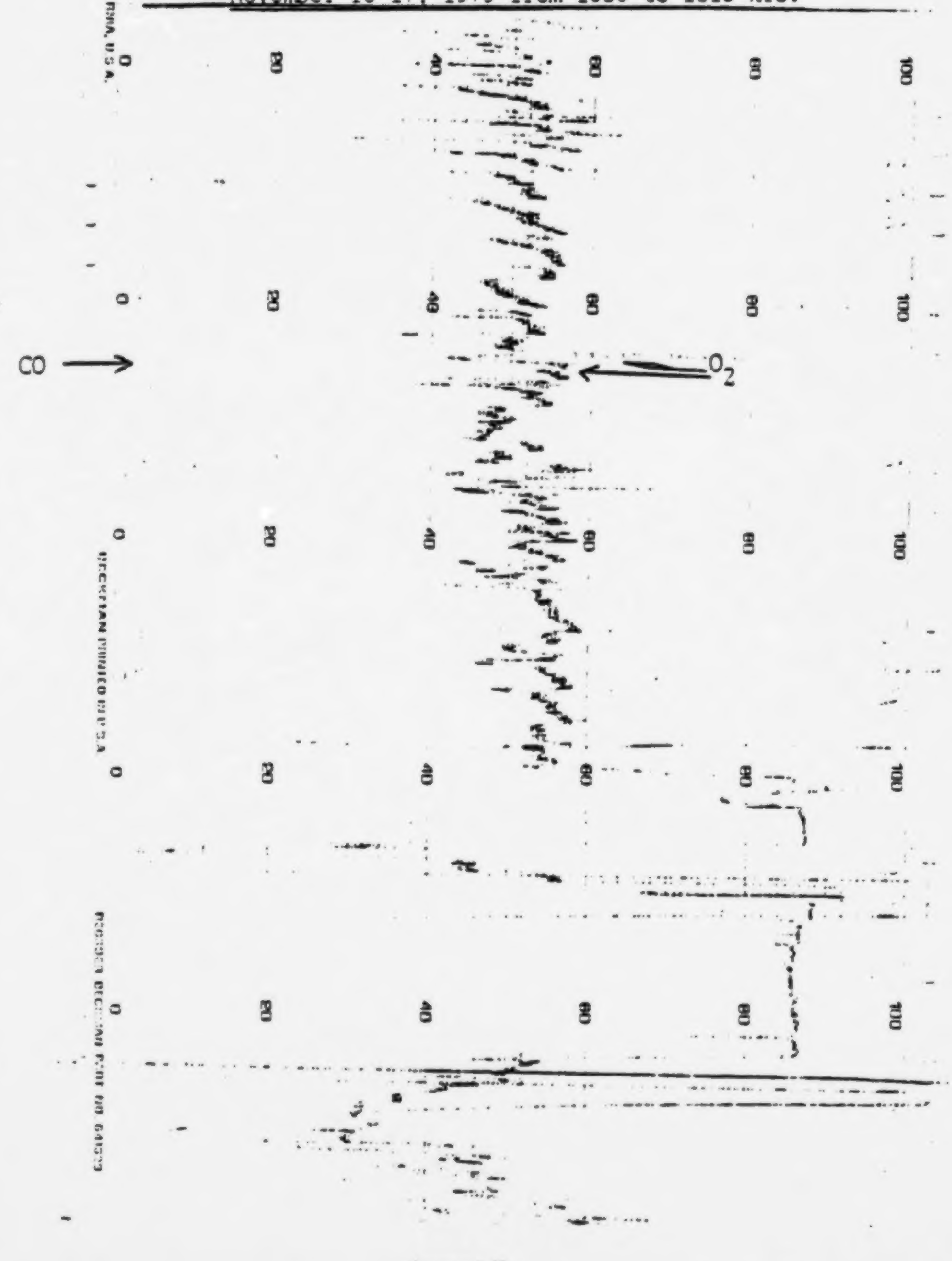


## FIGURE 15 (cont'd)

## CARBON MONOXIDE AND OXYGEN CONCENTRATIONS DURING THE PCB INCINERATION TEST

Incineration of Third Flush

November 16-17, 1979 from 1630 to 1315 hrs.



(cont'd)

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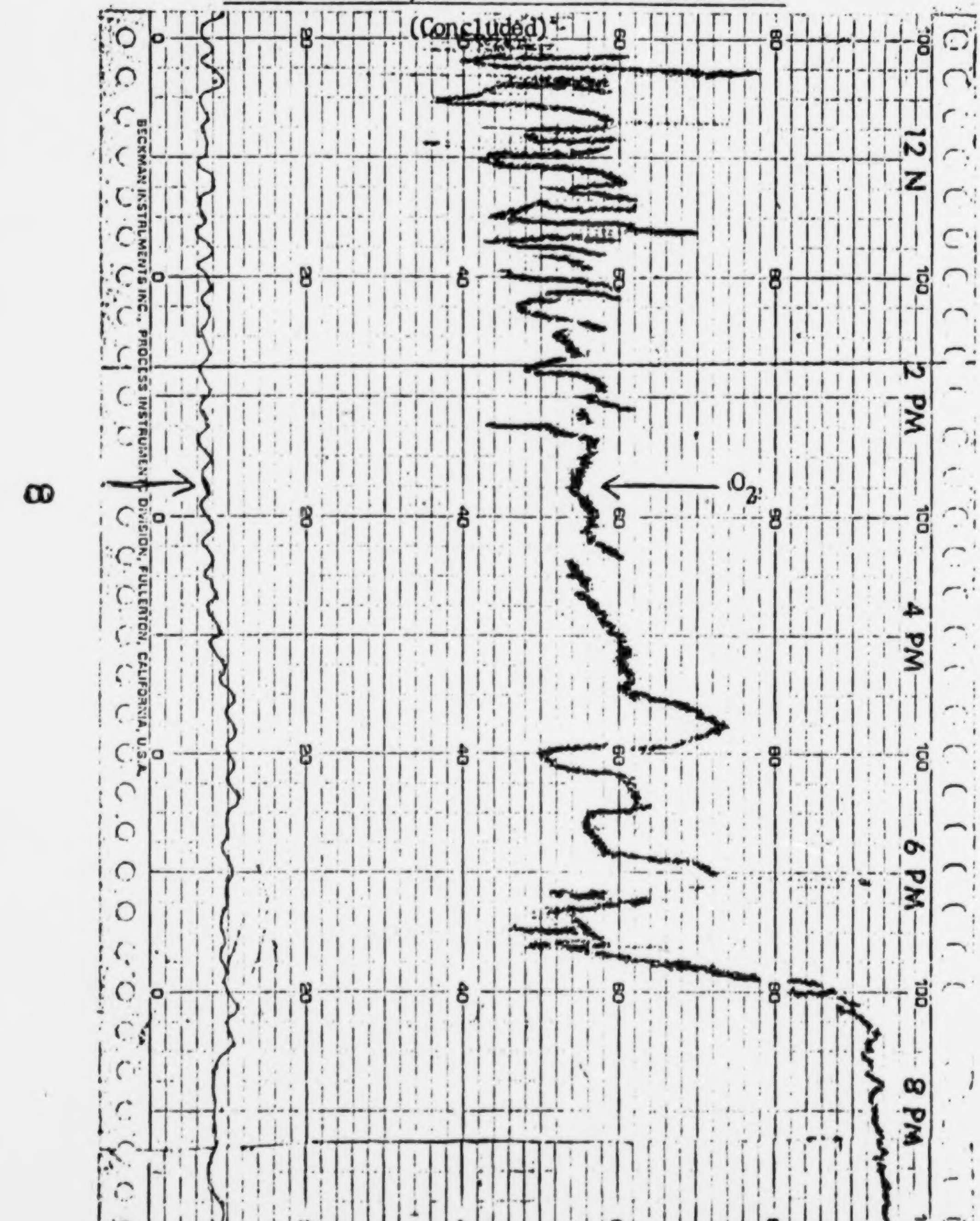
## FIGURE 15 (cont'd)

## CARBON MONOXIDE AND OXYGEN CONCENTRATIONS DURING THE PCB INCINERATION TEST

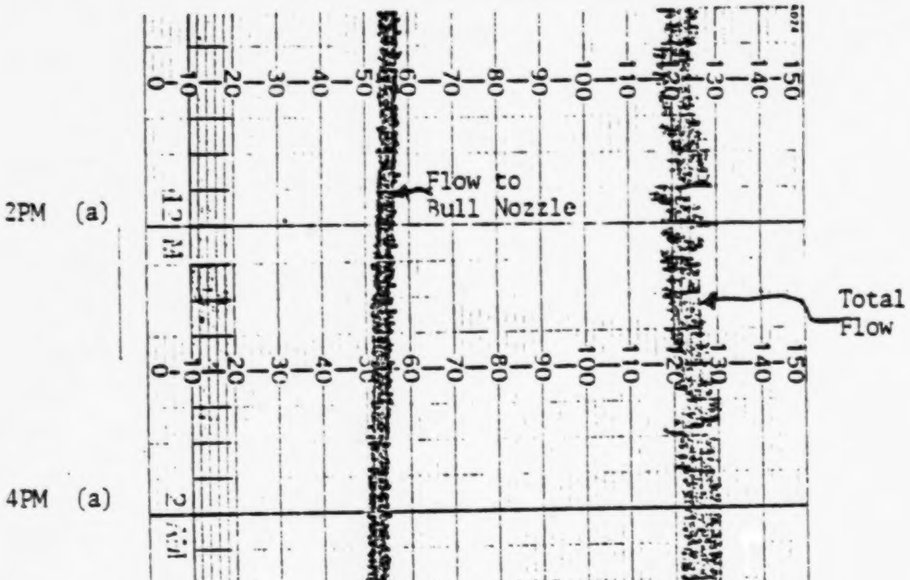
Incineration of Third Flush
November 16-17, 1979 from 1630 to 1315 hrs.
(Concluded)



## FIGURE 16

## WATER FLOWS TO SCRUBBER SYSTEM DURING PCB INCINERATION TEST

Run 1 incineration of background fuel
November 12, 1979 from 1400 to 2045 hrs.

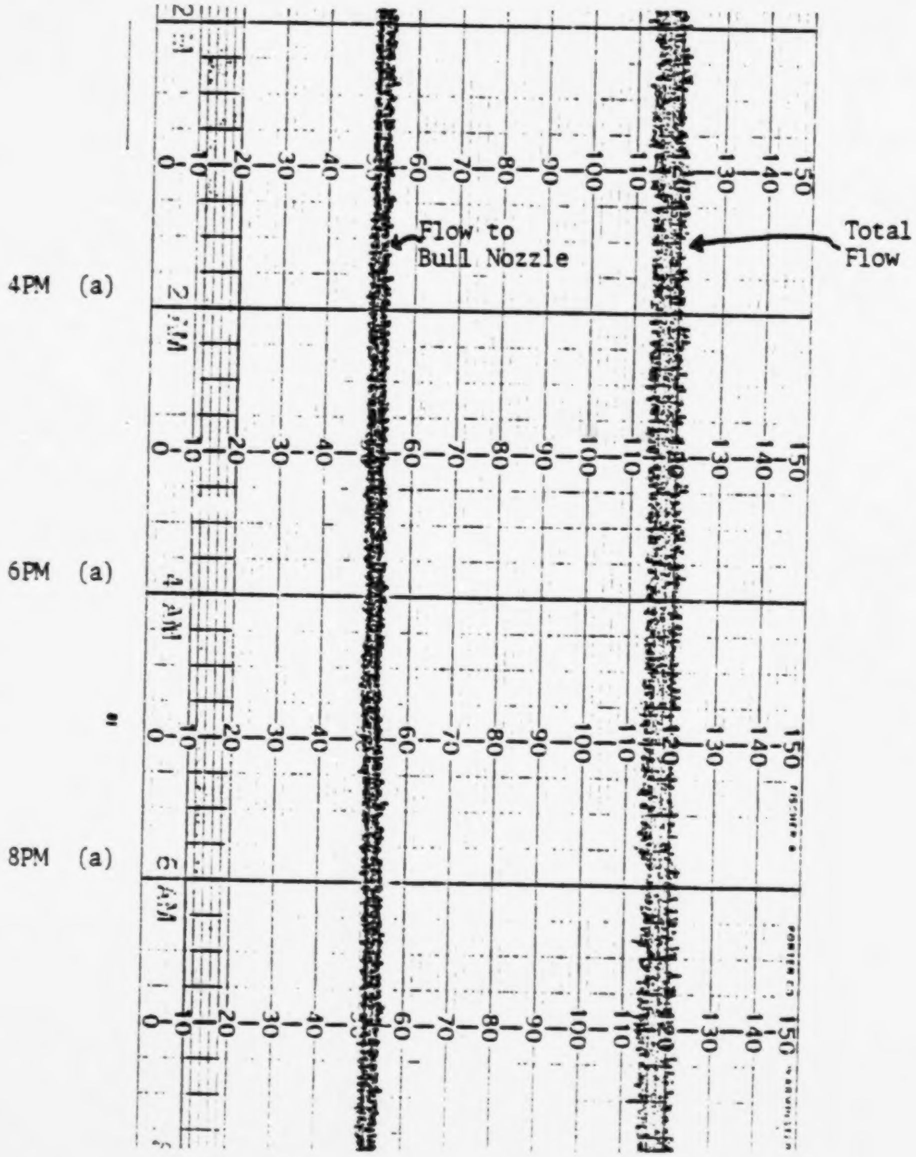


(a). Corrected time scale added.

FIGURE 16 (cont'd)

WATER FLOWS TO SCRUBBER SYSTEM DURING PCB INCINERATION TEST

Run 2 incineration of PCB fuel
November 13, 1979 from 1430 to 2115 hrs.



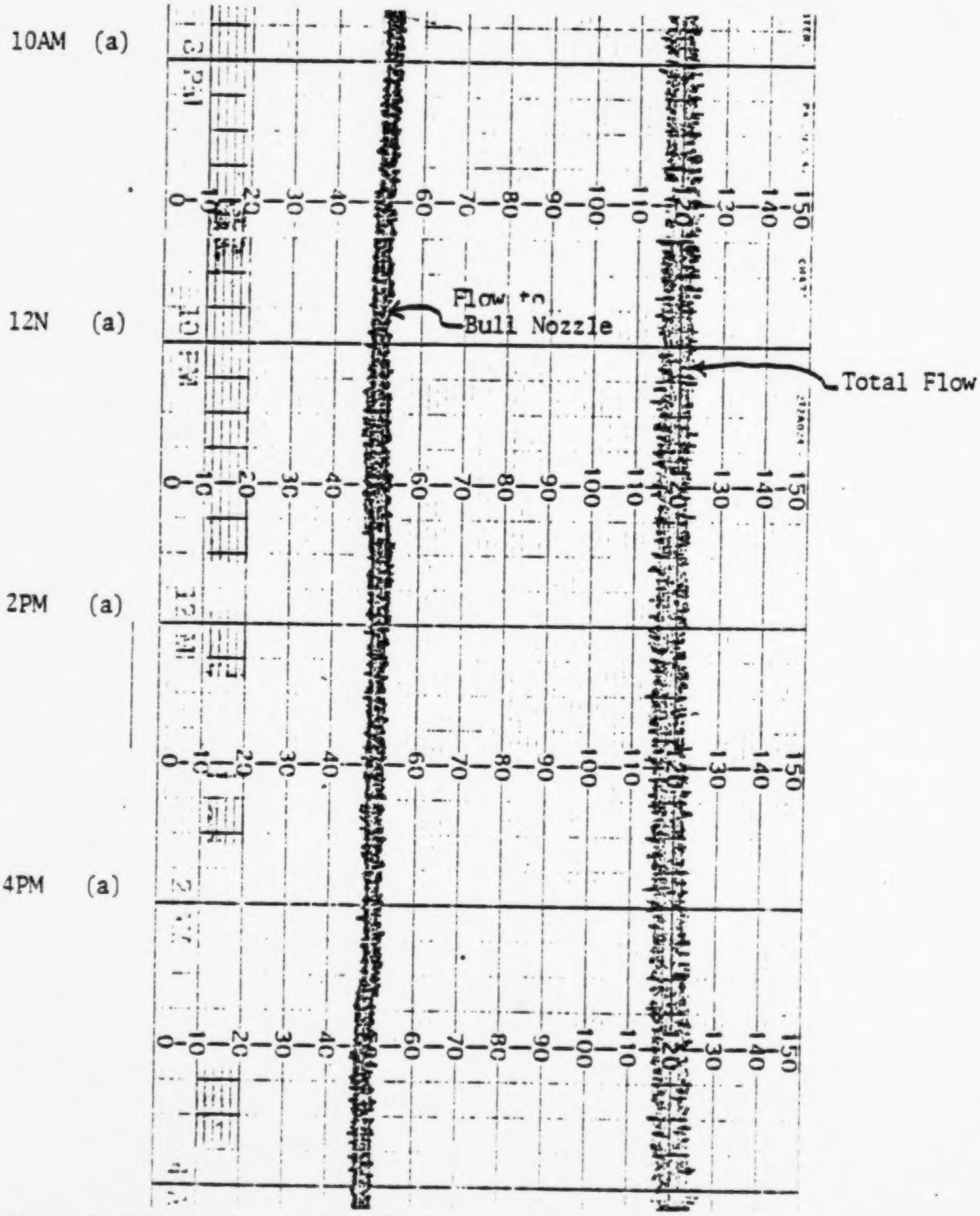
(a). Corrected time scale added.

238

## FIGURE 16 (cont'd)

## WATER FLOWS TO SCRUBBER SYSTEM DURING PCB INCINERATION TEST

Run 3 incineration of PCB fuel
November 14, 1979 from 1045 to 1730 hrs.



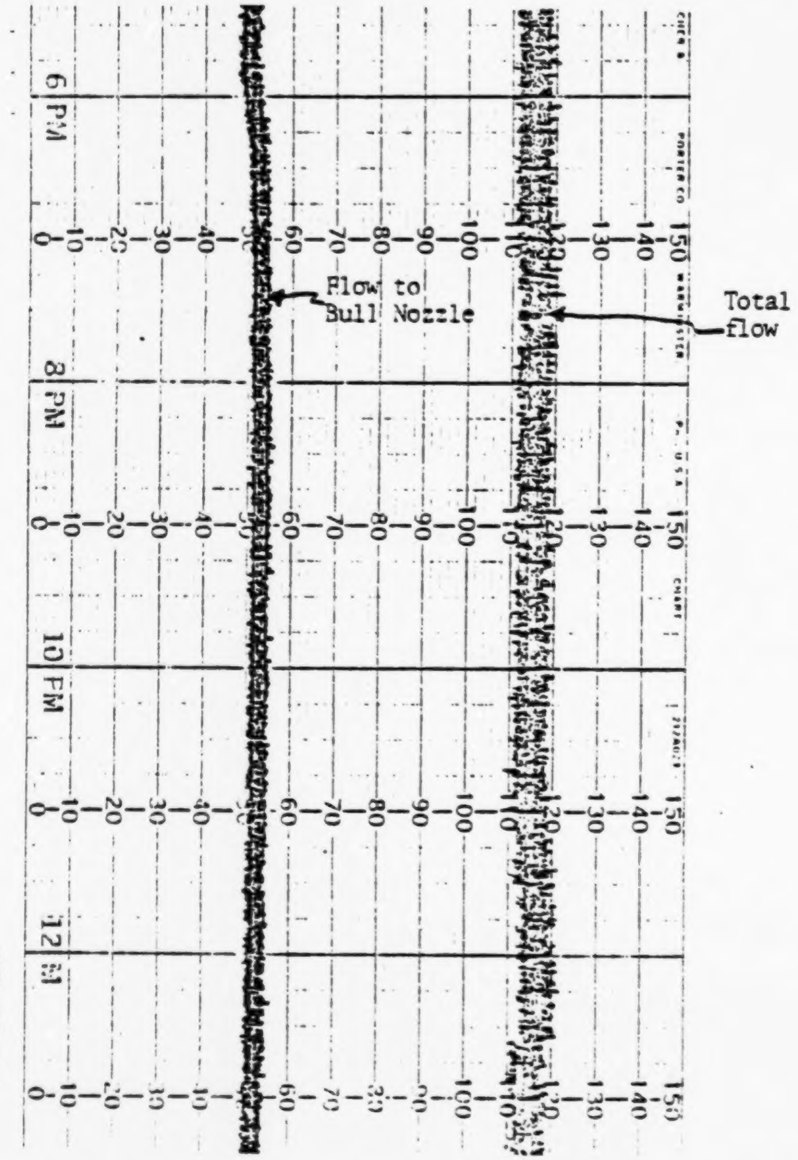
(a). Corrected time scale added.

339

FIGURE 16 (cont'd)

## WATER FLOW TO SCRUBBER SYSTEM DURING PCB INCINERATION TEST

Run 4 incineration of PCB fuel
November 15-16, 1979 from 1800 to 0100 hrs



## FIGURE 16 (cont'd)

## WATER FLOWS TO SCRUBBER SYSTEM DURING PCB INCINERATION TEST

Burn-out of excess PCB fuel

November 16, 1979 from 0108 to 0335 hrs.

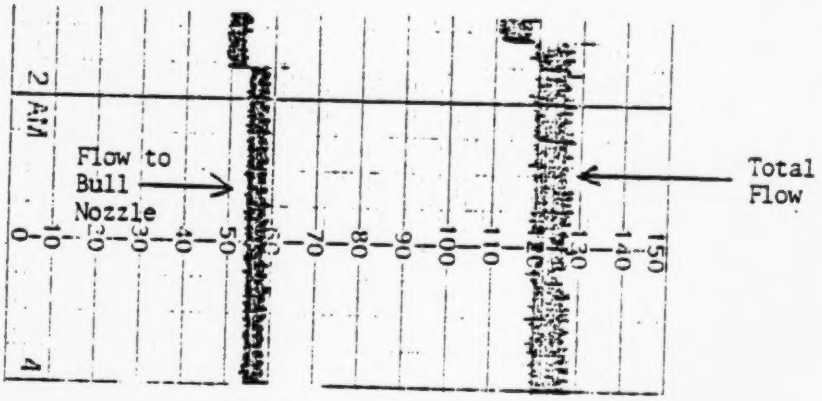


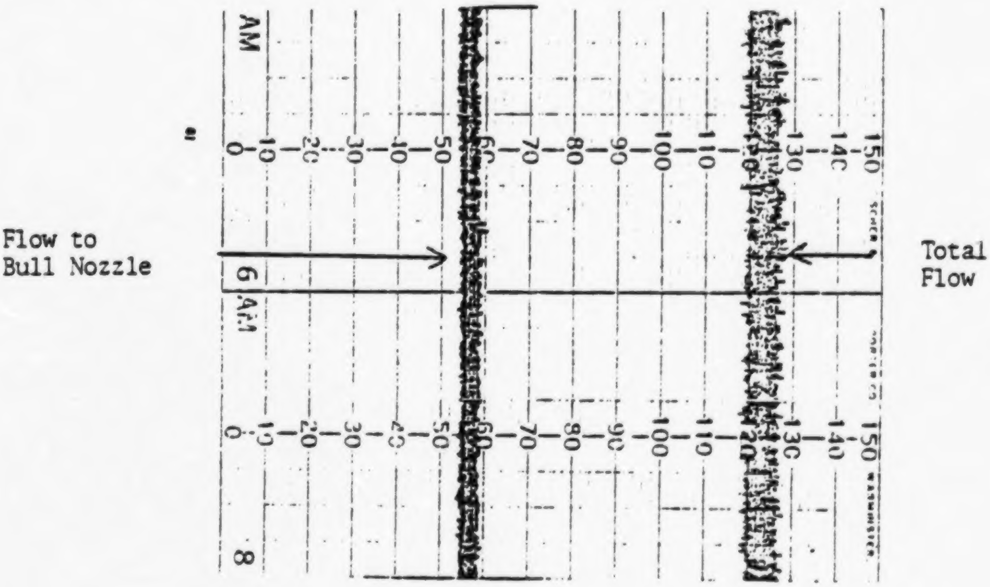
FIGURE 16 (cont'd)

WATER FLOWS TO SCRUBBER SYSTEM DURING

PCB INCINERATION TEST

Incineration of First Flush

November 16, 1979 from 0430 to 0730 hrs.



Flow to Bull Nozzle

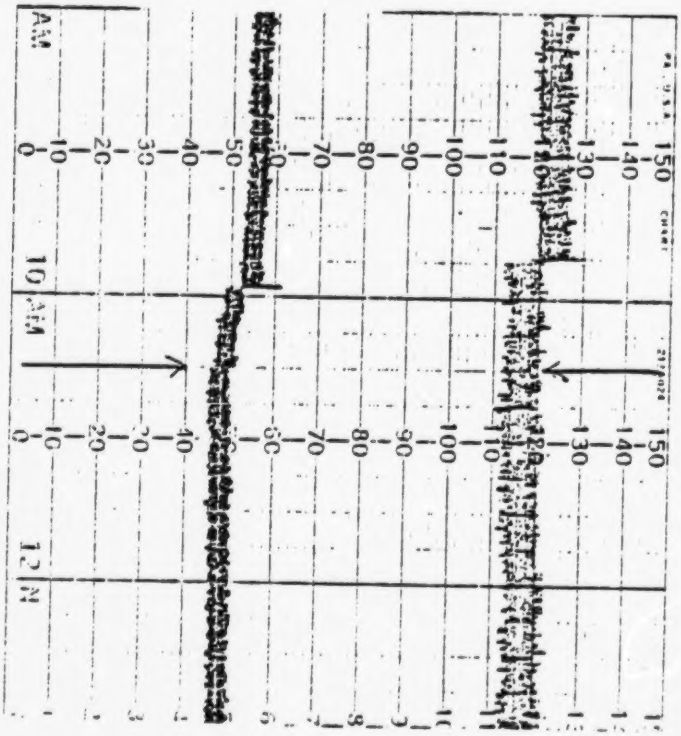
Total Flow

## FIGURE 16 (cont'd)

## WATER FLOWS TO SCRUBBER SYSTEM DURING PCB INCINERATION TEST

Incineration of Second Flush

November 16, 1979 from 0930 to 1215 hrs.



Flow to
Bull Nozzle

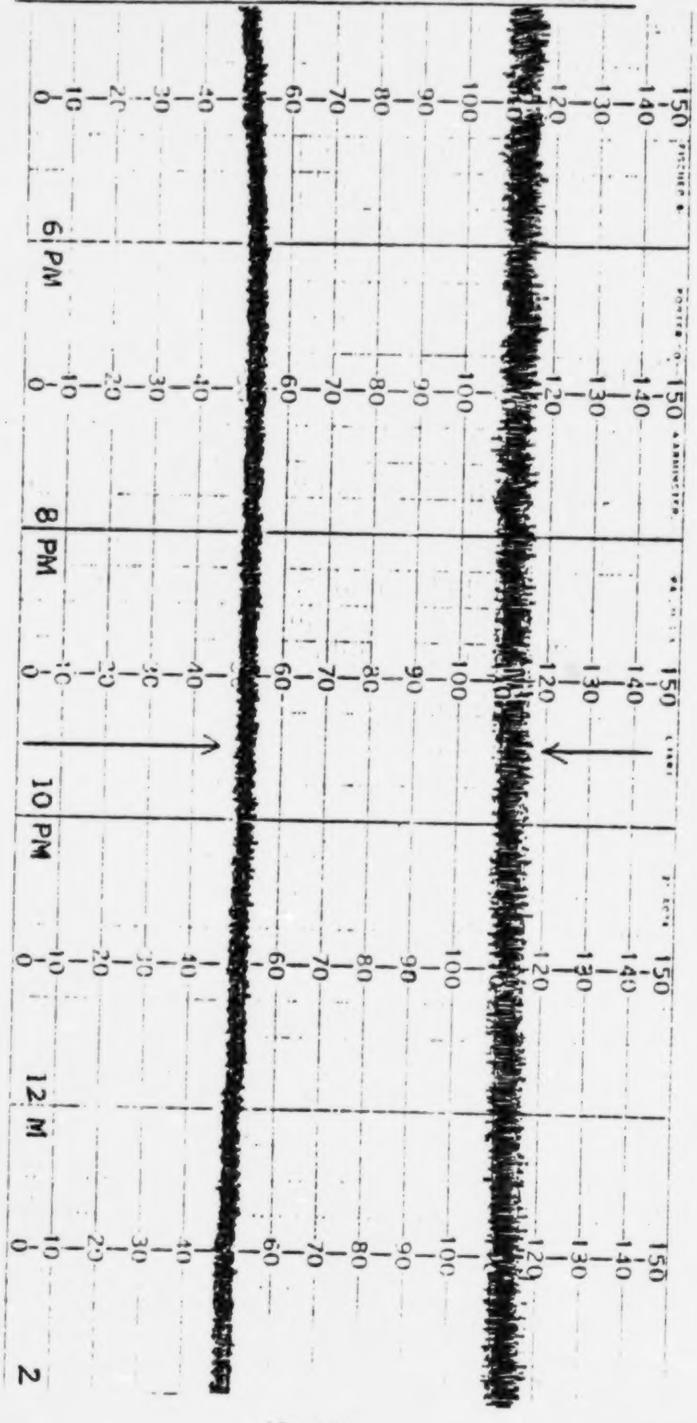
Total
Flow

FIGURE 16 (cont'd)

WATER FLOWS TO SCRUBBER SYSTEM DURING PCB INCINERATION TEST

Incineration of Third Flush

November 16-17, 1979 from 1915 to 1315 hrs.



Flow to Bull Nozzle

Total Flow

(Cont'd)

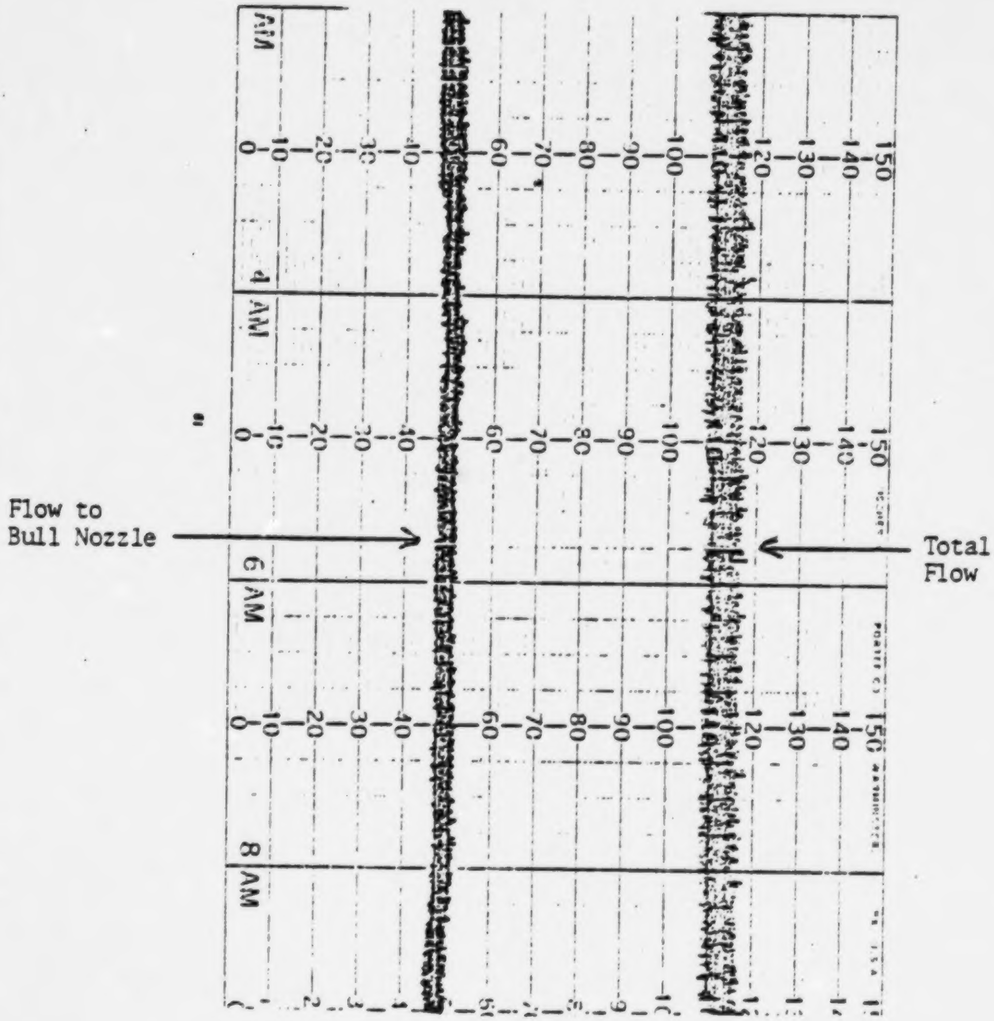
244

## FIGURE 16 (cont'd)

## WATER FLOWS TO SCRUBBER SYSTEM DURING PCB INCINERATION TEST

Incineration of Third Flush
November 16-17, 1979 from 1915 to 1315 hrs.

(cont'd)



## FIGURE 16 (cont'd)

WATER FLOWS TO SCRUBBER SYSTEM DURING
PCB INCINERATOR TEST

Incineration of Third Flush

November 16-17, 1979 from 1915 to 1315 hrs.

(concluded)

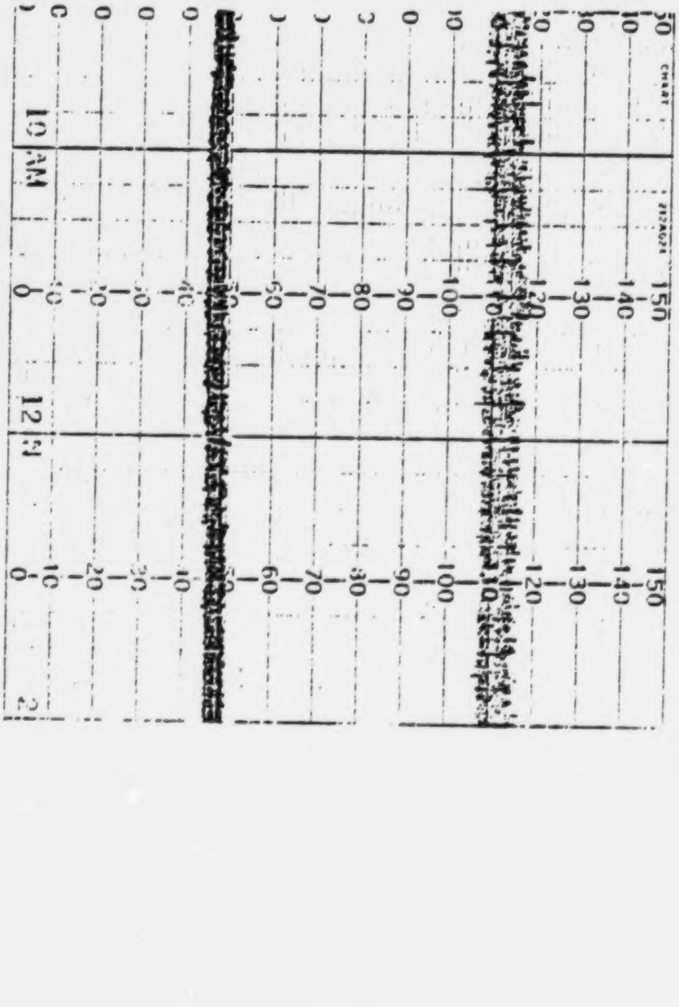


FIGURE 17

$\Delta$P ACROSS VENTURI THROAT DURING

THE PCB INCINERATION TESTS

November 12-16, 1979

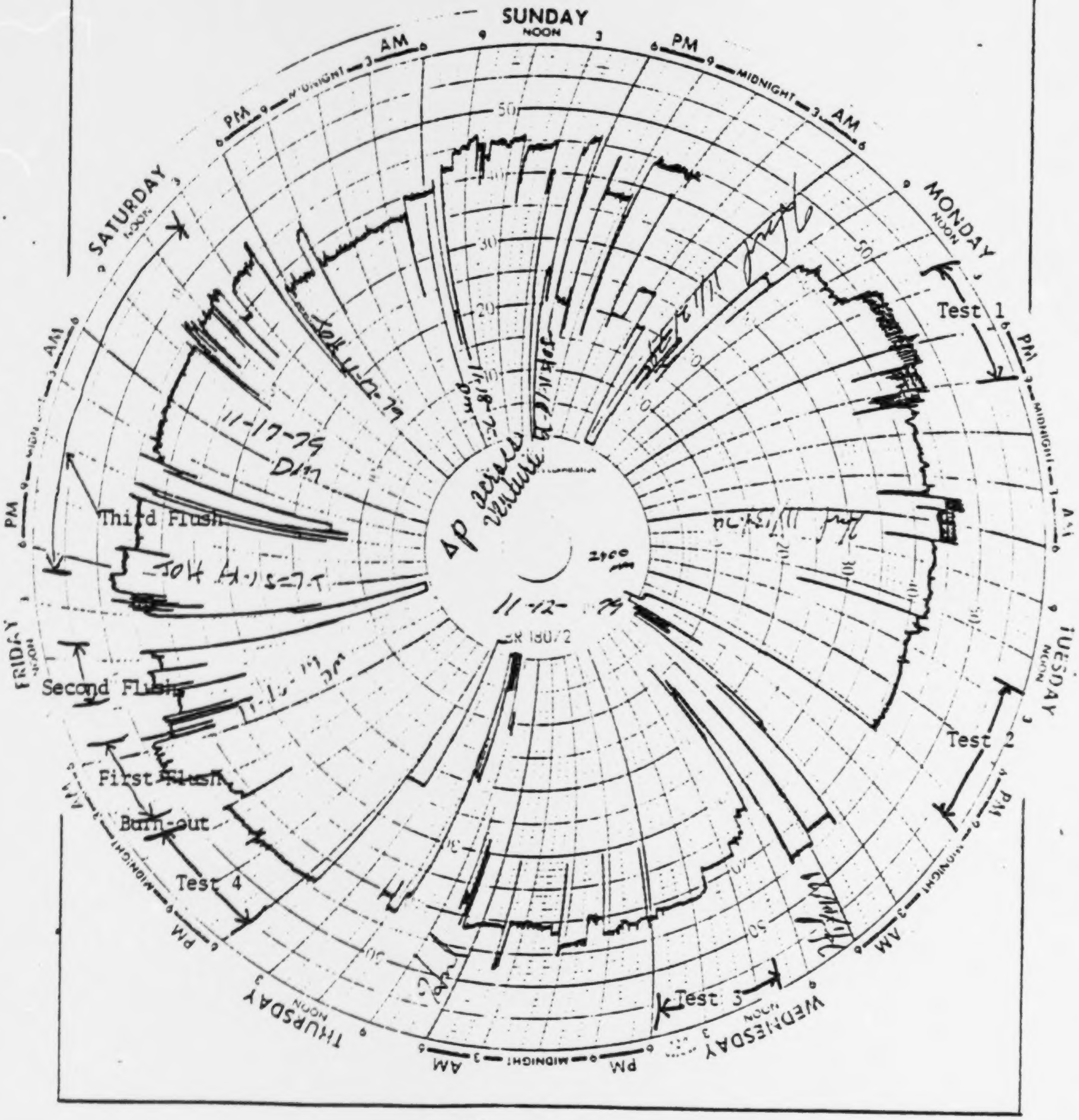


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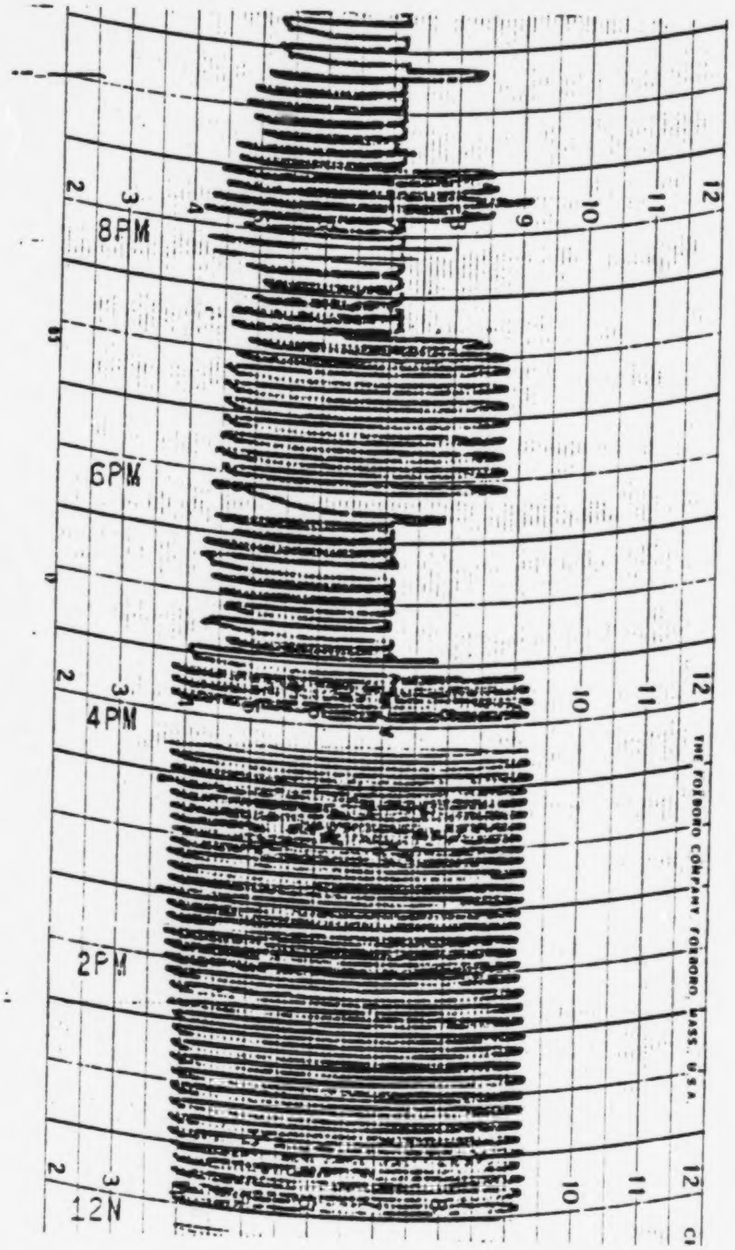
FIGURE 18

SCRUB WATER RETENTION TANK: $p^H$ DURING

THE PCB INCINERATION TEST

Run 1 incineration of background fuel

November 12, 1979 from 1400 to 2045 hrs



## FIGURE 18 (cont'd)

## SCRUB WATER RETENTION TANK: $p^H$ DURING THE PCB INCINERATION TEST

Run 2 incineration of PCB fuel
November 13, 1979 from 1430 to 2115 hrs.

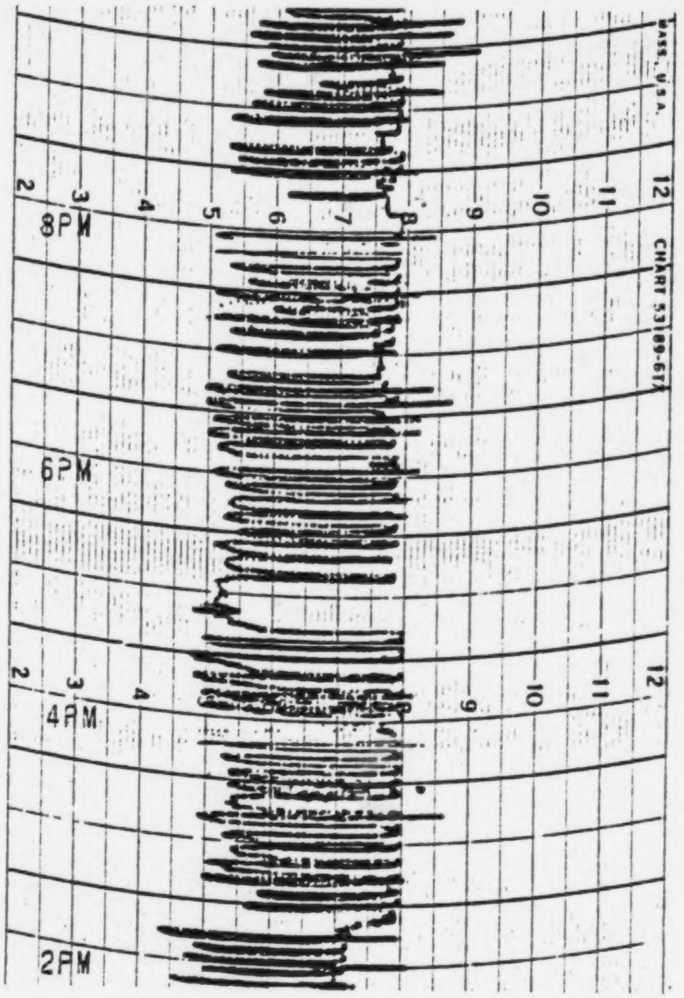


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FIGURE 18 (cont'd)

SCRUB WATER RETENTION TANK: pH DURING THE PCB INCINERATION TEST

Run 3 incineration of PCB fuel

November 14, 1979 from 1045 to 1730 hrs.

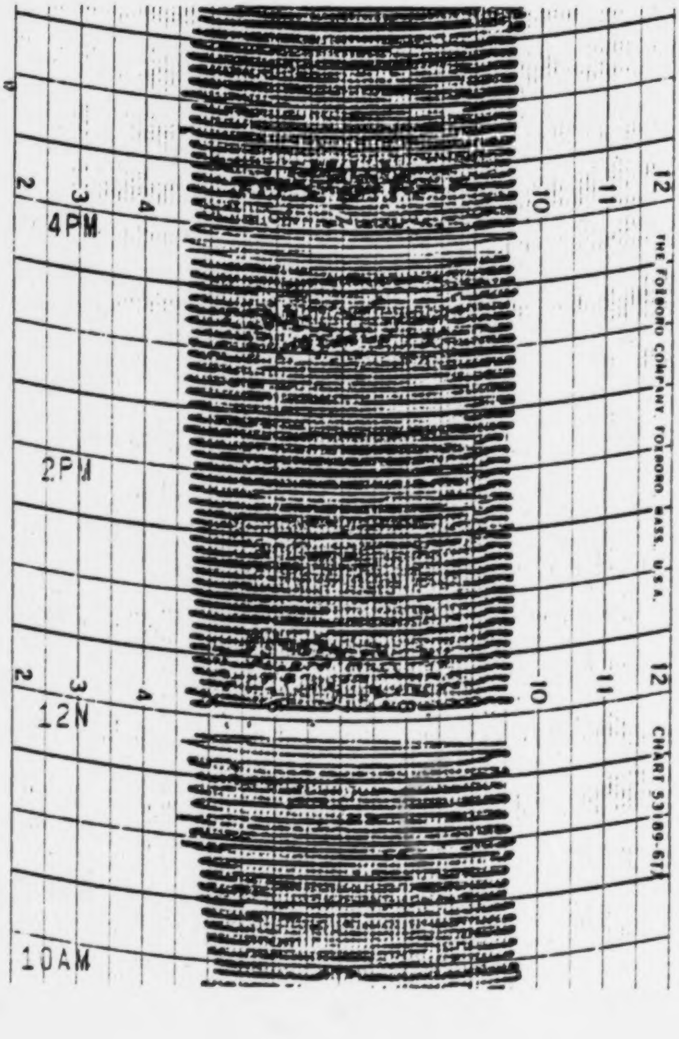


FIGURE 18 (cont'd)

SCRUB WATER RETENTION TANK: pH DURING

THE PCB INCINERATION TEST

Run 4 incineration of PCB fuel

November 15-16, 1979 from 1800 to 0100 hrs.

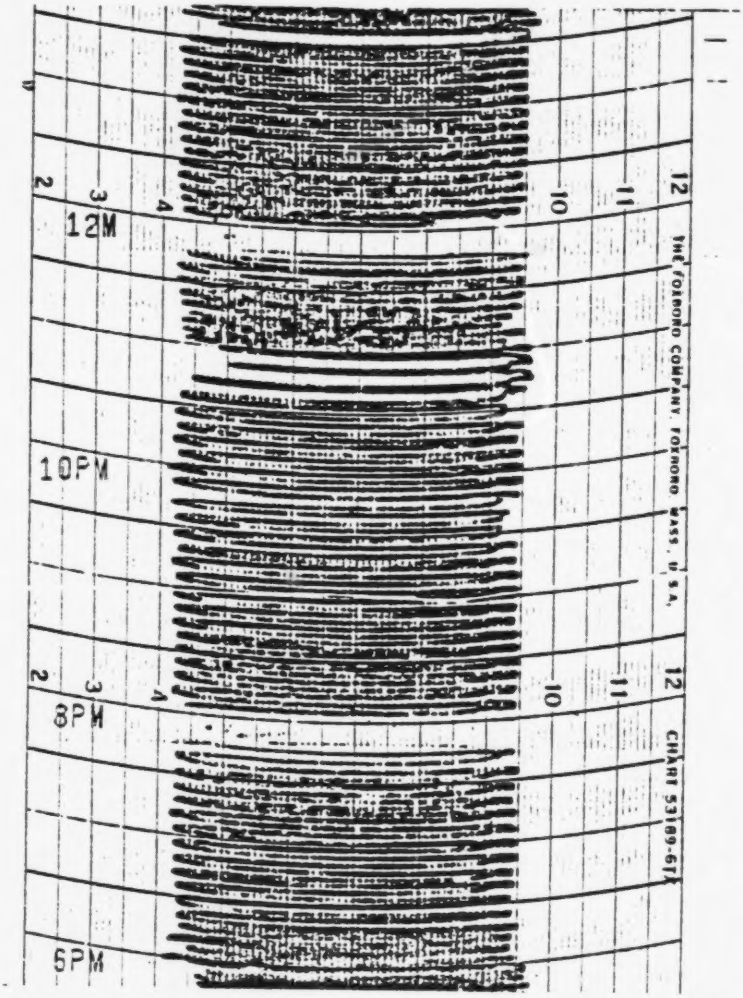


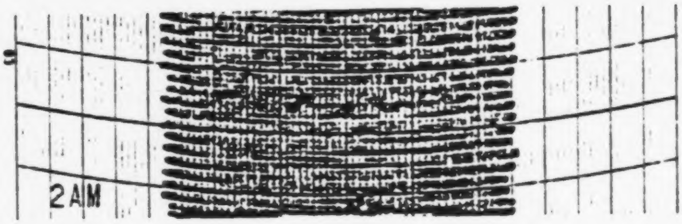
FIGURE 18 (cont'd)

SCRUB WATER RETENTION TANK: pH DURING

THE PCB INCINERATION TEST

Burn-out of excess PCB fuel

November 16, 1979 from 0108 to 0335 hrs.



## FIGURE 18 (cont'd)

## SCRUB WATER RETENTION TANK: pH DURING THE PCB INCINERATION TEST

Incineration of First Flush

November 16, 1979 from 0430 to 0730 hrs.

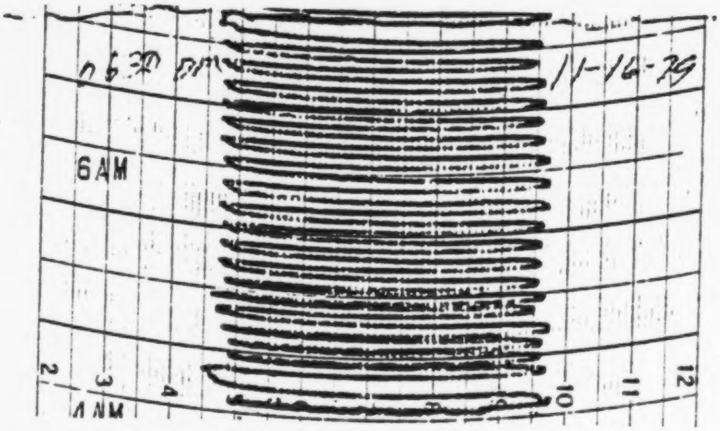


FIGURE 18 (cont'd)

SCRUB WATER RETENTION TANK: pH DURING
THE PCB INCINERATION TEST

Incineration of Second Flush
November 16, 1979 from 0930 to 1215 hrs.

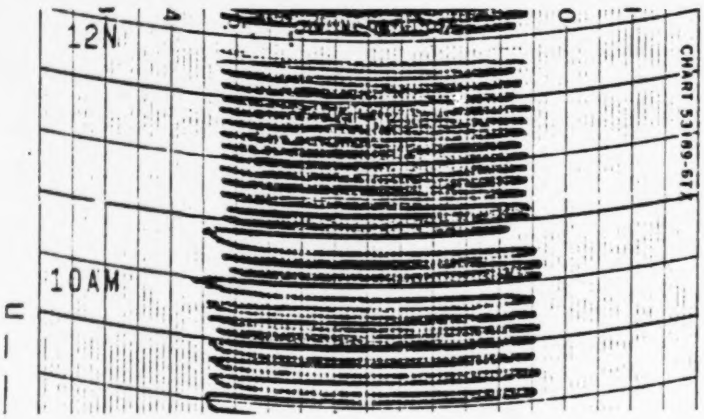
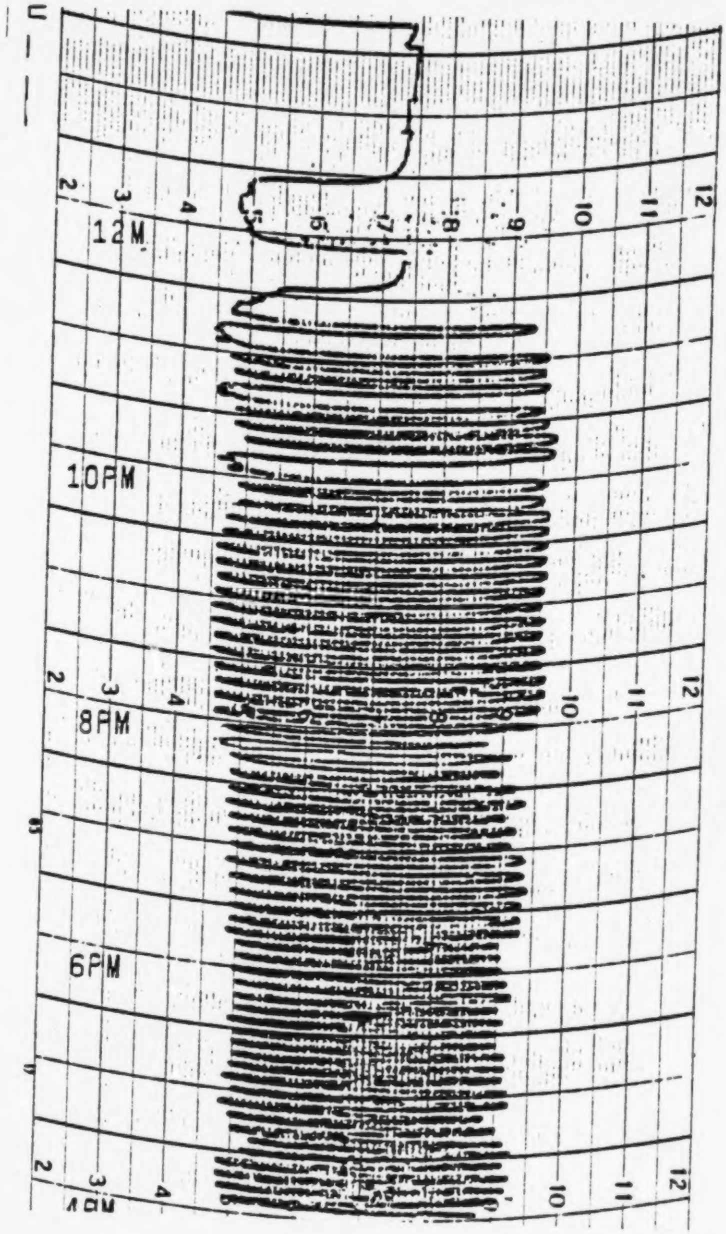


FIGURE 18 (cont'd)

SCRUB WATER RETENTION TANK: pH DURING
THE PCB INCINERATION TEST

Incineration of Third Flush
November 16-17, 1979 from 1630 to 1315 hrs.



(cont'd)

FIGURE 18 (cont'd)

SCRUB WATER RETENTION TANK: pH DURING THE PCB INCINERATION TEST

Incineration of Third Flush

November 16-17, 1979 from 1630 to 1315 hrs.

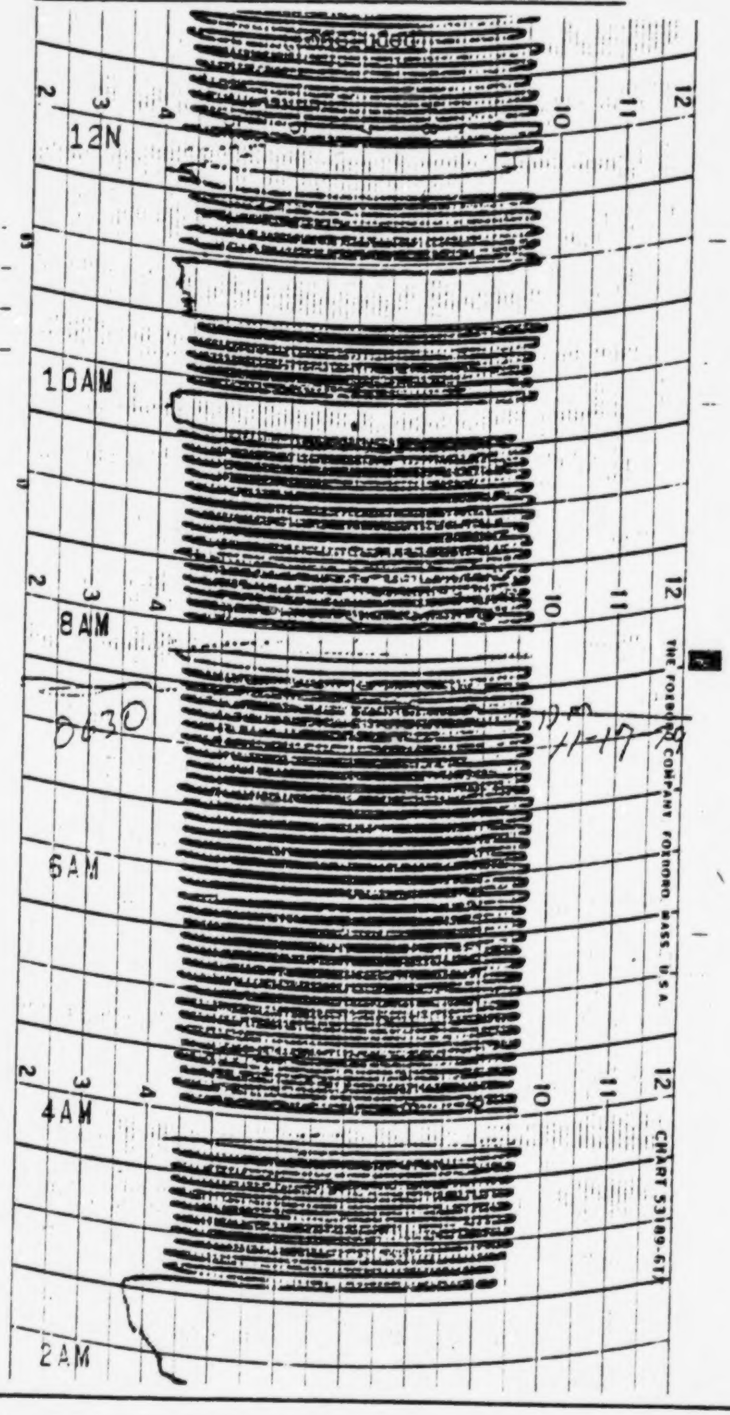


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FIGURE 19

THE $p^H$ OUTFALL 001 DURING THE

PCB INCINERATION TEST

Test 1 incineration of background fuel

November 12, 1979 from 1400 to 2045 hrs.

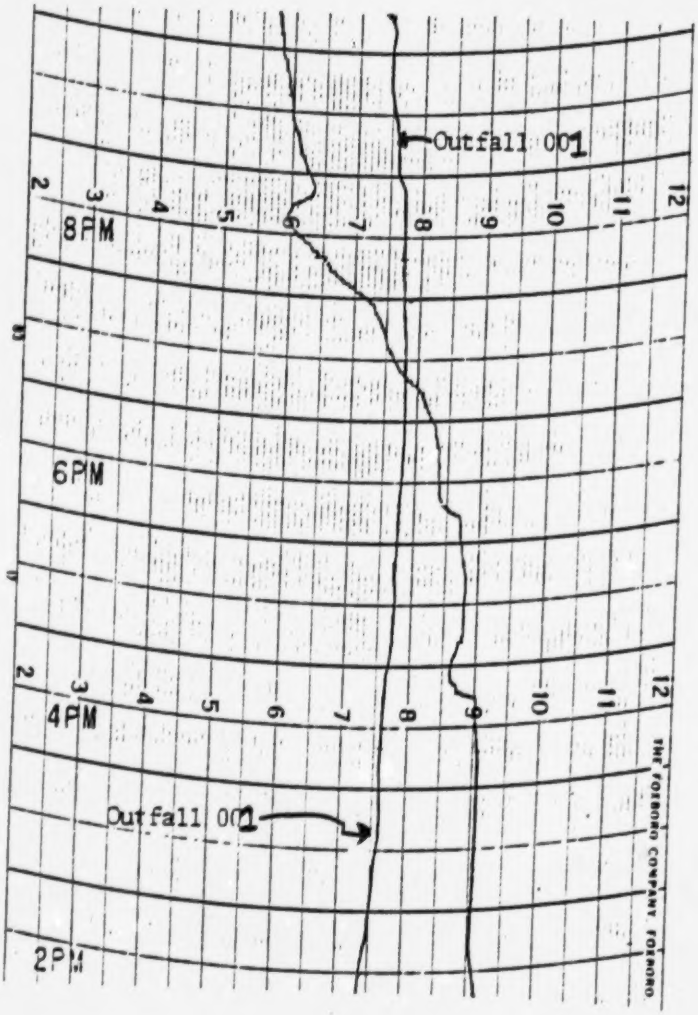


FIGURE 19 (cont'd)

THE $p^H$ AT OUTFALL 001 DURING THE

PCB INCINERATION TEST

Test 3 incineration of PCB fuel

November 14, 1979 from 1045 to 1730 hrs.

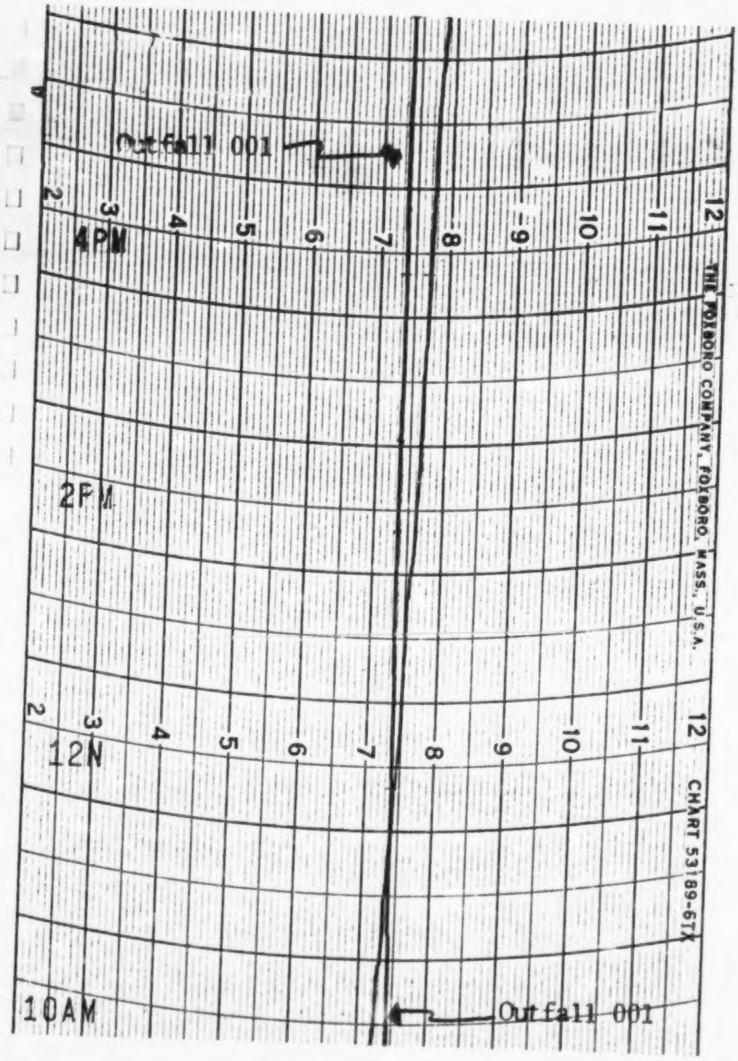


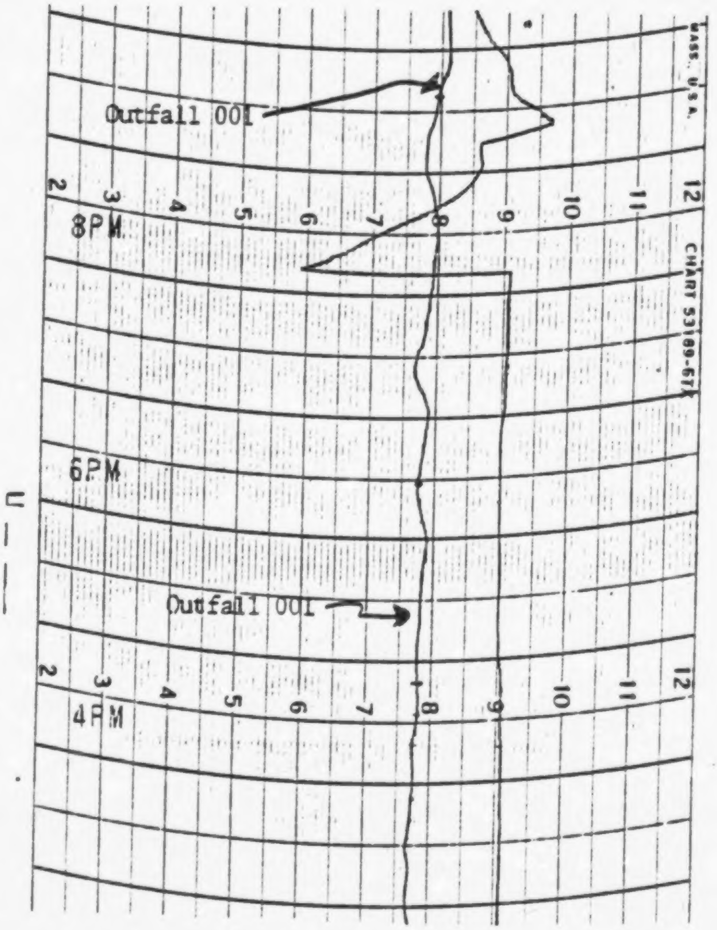
FIGURE 19 (cont'd)

THE $p^H$ AT OUTFALL 001 DURING THE

PCB INCINERATION TEST

Test 2 incineration of PCB fuel

November 13, 1979 from 1430 to 2115 hrs.



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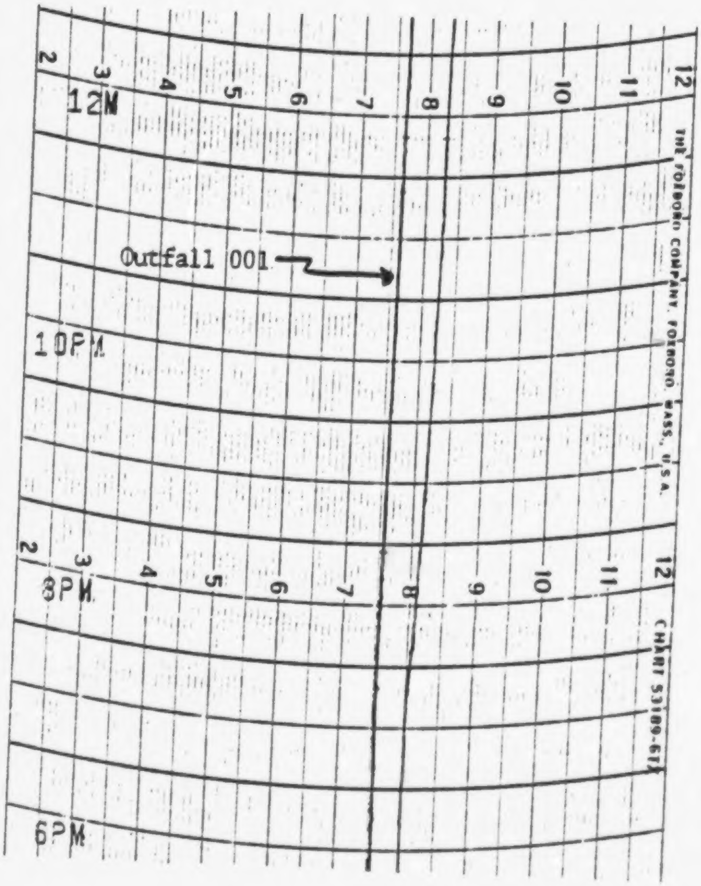
## FIGURE 19 (cont'd)

## THE $p^H$ AT OUTFALL 001 DURING THE PCB INCINERATION TEST

Test 4 incineration of PCB fuel

November 15-16, 1979 from 1800 to 0100 hrs.



260

FIGURE 19 (cont'd)

THE pH OUTFALL 001 DURING THE
PCB INCINERATION TEST

Burn-out of excess PCB fuel
November 16, 1979 from 0108 to 0335 hrs.

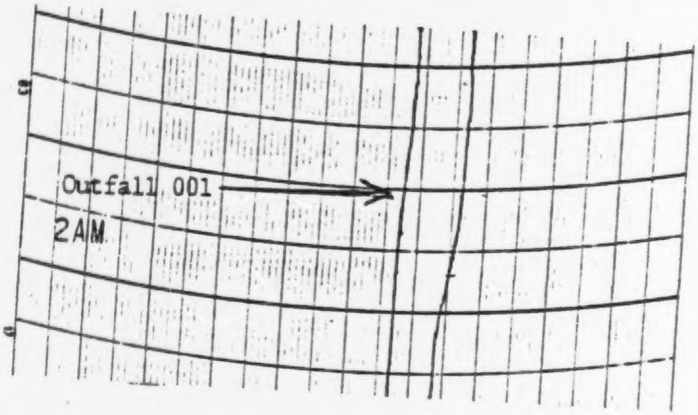
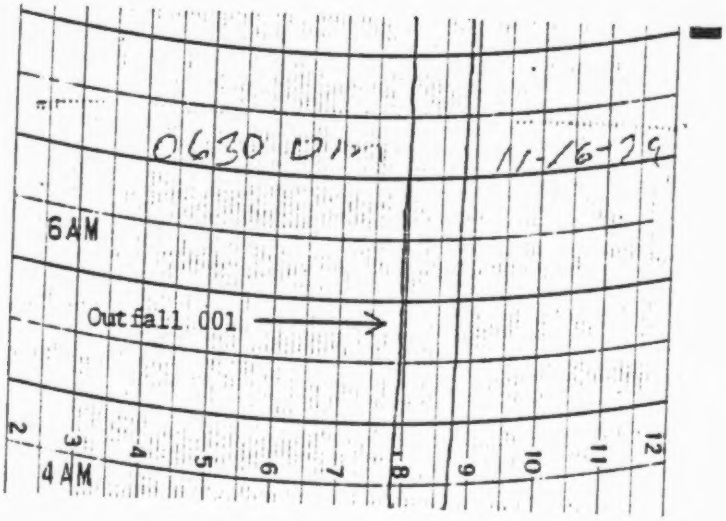


FIGURE 19 (cont'd)

## THE pH AT OUTFALL 001 DURING THE PCB INCINERATION TEST

Incineration of First Flush

November 16, 1979 from 0430 to 0730 hrs.

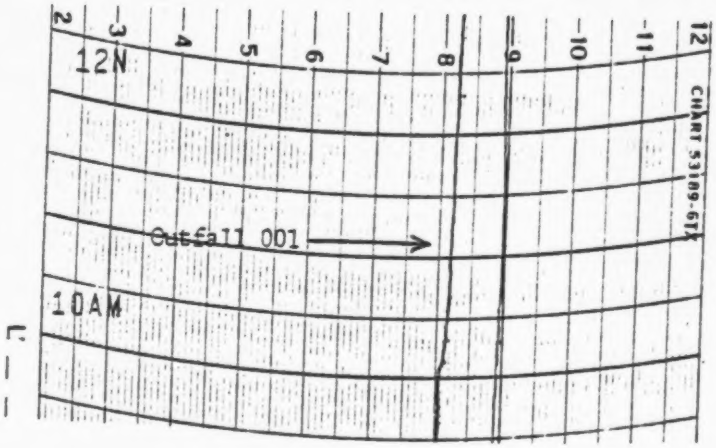


## FIGURE 19 (cont'd)

## THE pH AT OUTFALL 001 DURING THE PCB INCINERATION TEST

Incineration of Second Flush

November 16, 1979 from 0930 to 1215 hrs.



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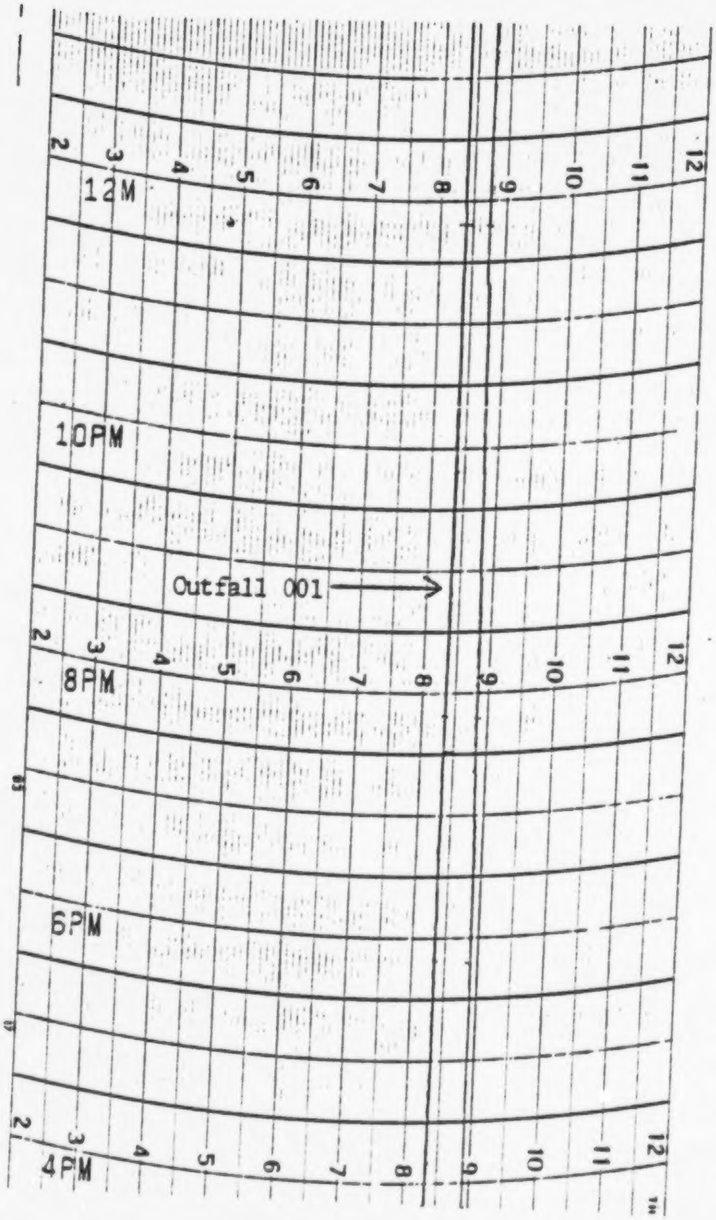
## FIGURE 19 (cont'd)

## THE pH AT OUTFALL 001 DURING THE PCB INCINERATION TEST

Incineration of Third Flush

November 16-17, 1979 from 1630 to 1315 hrs.



(cont'd)

264

## FIGURE 19 (cont'd)

## THE pH OF OUTFALL 001 DURING THE PCB INCINERATION TEST

Incineration of Third Flush
November 16-17, 1979 from 1630 to 1315 hrs.

(cont'd)

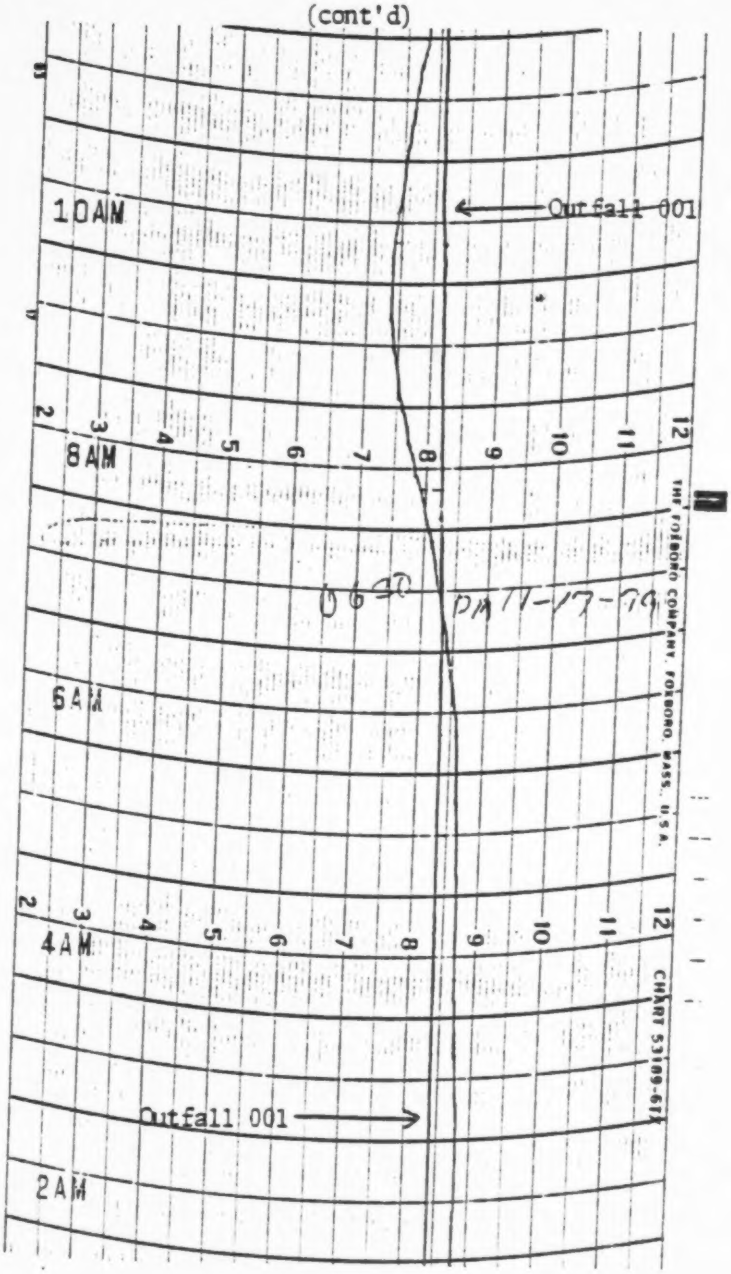


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FIGURE 19 (cont'd)

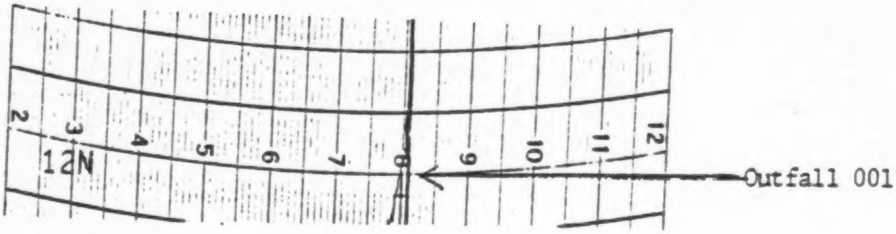
THE pH OF OUTFALL 001 DURING THE

PCB INCINERATION TEST

Incineration of Third Flush

November 16-17, 1979 from 1630 to 1315 hrs.

(concluded)



# APPENDIX I

## TRIAL TEST OF LIQUID PCB INCINERATION

BY: ROLLINS ENVIRONMENTAL SERVICES (TX), INC.

DATE 11/12/1979
RUN # 1 (Background)

PAGE 1

| TIME HOURS | TEMPERATURES (°F) | | | | | MONITORS | | | FANS (%) OPENED | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Hot duct | Afterburner | Kiln | Stack | Ambient | CO (PPM) | $O_2$ (%) | $CO_2$ (%) | Forced air | ID |
| 1400 | 2145 | 2374 | 1606 | | 62.5 | 1.75 | 8.15 | | 67 | 32 |
| 1415 | 2174 | 2311 | 1412 | | 62.5 | 1.50 | 8.15 | | 67 | 32 |
| 1430 | 2121 | 2202 | 1323 | | 62.5 | 1.25 | 7.73 | | 67 | 32 |
| 1445 | 2153 | 2317 | 1345 | | 62.5 | 0.50 | 7.94 | | 67 | 32 |
| 1500 | 2181 | 2291 | 1389 | | 63.0 | 0.50 | 8.51 | | 65 | 32 |
| 1515 | 2185 | 2288 | 1390 | | 63.0 | 1.00 | 8.57 | | 65 | 32 |
| 1530 | 2184 | 2290 | 1399 | | 63.5 | 0.00 | 8.18 | | 65 | 32 |
| 1545 | 2170 | 2274 | 1340 | | 63.5 | 0.00 | 8.57 | | 65 | 32 |
| 1600 | 2184 | 2258 | 1377 | | 63.5 | 0.00 | 8.99 | | 65 | 32 |
| 1615 | 2183 | 2268 | 1379 | | 63.0 | 0.75 | 8.51 | | 65 | 32 |
| 1630 | 2183 | 2268 | 1374 | | 62.5 | 0.00 | 9.41 | | 65 | 32 |
| 1645 | 2183 | 2268 | 1380 | | 62.0 | 0.00 | 9.41 | | 65 | 34 |
| 1700 | 2175 | 2288 | 1326 | | 61.5 | 0.00 | 9.82 | | 65 | 34 |
| 1715 | 2197 | 2353 | 1309 | | 61.0 | 0.00 | 9.82 | | 65 | 33 |
| 1730 | 2159 | 2244 | 1374 | | 61.0 | 0.00 | 10.24 | | 65 | 34 |
| 1745* | 1727 | 2186 | 818 | | 61.0 | 6.0 | 10.24 | | 65 | 32 |

* 1738 - we had a plug off pressure feed tractor; temps dropped and temp shutdown device activated @ 2040 °F.

# TRIAL TEST OF LIQUID PCB INCINERATION

BY: ROLLINS ENVIRONMENTAL SERVICES (TX), INC.

DATE 11/12/1979 PAGE 2
RUN # 1 (Background)

| TIME HOURS | TEMPERATURES (°F) |  |  |  |  | MONITORS |  |  | FANS (%) OPENED |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Hot duct | Afterburner | Kiln | Stack | Ambient | CO (PPM) | $O_2$ (%) | $CO_2$ (%) | Forced air | ID |
| 1800 | 2210 | 2358 | 1501 |  | 61.0 | 0.00 | 10.24 |  | 65 | 34 |
| 1815 | 2146 | 2365 | 1310 |  | 61.0 | 0.50 | 9.82 |  | 65 | 33 |
| 1830 | 2193 | 2304 | 1366 |  | 61.0 | 1.00 | 10.87 |  | 65 | 33 |
| 1845 | 2177 | 2322 | 1361 |  | 61.0 | 0.50 | 10.45 |  | 65 | 33 |
| 1900 | 2190 | 2333 | 1360 |  | 61.0 | 1.25 | 10.87 |  | 65 | 34 |
| 1915 | 2194 | 2350 | 1385 |  | 61.0 | 1.00 | 10.45 |  | 65 | 33 |
| 1930 | 2197 | 2311 | 1375 |  | 60.5 | 1.00 | 11.08 |  | 65 | 32 |
| 1945 | 2185 | 2336 | 1387 |  | 60.0 | 0.50 | 10.24 |  | 65 | 33 |
| 2000 | 2183 | 2333 | 1381 |  | 60.0 | 1.75 | 10.45 |  | 65 | 30 |
| 2015 | 2184 | 2328 | 1375 |  | 59.0 | 1.50 | 10.03 |  | 65 | 30 |
| 2030 | 2185 | 2340 | 1363 |  | 58.5 | 1.75 | 10.03 |  | 65 | 30 |
| 2045 | 2188 | 2336 | 1358 |  | 58.0 | 2.25 | 10.24 |  | 65 | 31 |

## TRIAL TEST OF LIQUID PCB INCINERATION

BY: ROLLINS ENVIRONMENTAL SERVICES (TX), INC.

page #1

DATE 11/13/1979
RUN # 2 (PCB run)

1422 = flow of PCB's initiated thru flowmeter

| TIME HOURS | TEMPERATURES (°F) Hot duct | Afterburner | Kiln | Stack | Ambient | MONITORS CO (PPM) | O2 (%) | CO2 (%) | FANS (%) OPENED Forced air | ID |
|---|---|---|---|---|---|---|---|---|---|---|
| 1430 | 2110 | 2269 | 1422 | | 68<br>[illegible].0 | 4.5 | 7.32 | | 72 | 20 |
| 1445 | 2200 | 2269 | 1526 | | 67.0 | 6.0 | 7.32 | | 70 | 23 |
| 1500 | 2225 | 2274 | 1423 | | 66.5 | 4.0 | 7.32 | | 70 | 20 |
| 1515 | 2221 | 2241 | 1400 | | 65.0 | 6.5 | 7.73 | | 70 | 20 |
| 1530 | 2183 | 2211 | 1376 | | 64.5 | 6.0 | 8.15 | | 70 | 22 |
| 1545 | 2163 | 2218 | 1420 | | 63.0 | 5.5 | 8.15 | | 70 | 20 |
| 1600* | 2150 | 2230 | 1442 | | 62.5 | 5.0 | 8.90 | | 70 | 20 |
| 1615 | 2035 | 2236 | 1359 | | 61.5 | 4.0 | 9.20 | | 10 | 20 |
| 1630 | 2202 | 2306 | 1493 | | 60.5 | 5.5 | 7.73 | | 70 | 20 |
| 1645 | 2182 | 2346 | 1551 | | 60.0 | 5.0 | 8.36 | | 70 | 23 |
| 1700 | 2173 | 2357 | 1523 | | 59.5 | 6.0 | 8.36 | | 70 | 21 |
| 1715 | 2144 | 2400 | 1540 | | 59.0 | 5.5 | 8.36 | | 70 | 20 |
| 1730 | 2134 | 2351 | 1518 | | 58.0 | 5.0 | 9.20 | | 70 | 22 |
| 1745 | 2107 | 2346 | 1535 | | 58.0 | 5.0 | 9.41 | | 70 | 20 |
| 1800 | 2136 | 2380 | 1553 | | 57.5 | 6.5 | 9.20 | | 10 | 20 |

*1605 = off PCB's because PCB train on stack is plugged up; back on PCB flow @ 1625 HRS

page #2

TRIAL TEST OF LIQUID PCB INCINERATION

BY: ROLLINS ENVIRONMENTAL SERVICES (TX), INC.

DATE 11/13/1979
RUN # 2 (PCB burn)

| TIME HOURS | TEMPERATURES (°F) |  |  |  |  | MONITORS |  |  | FANS (%) OPENED |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Hot duct | Afterburner | Kiln | Stack | Ambient | CO (PPM) | O2 (%) | CO2 (%) | Forced air | ID |
| 1815 | 2154 | 2399 | 1554 |  | 57.0 | 6.0 | 8.57 |  | 70 | 20 |
| 1830 | 2163 | 2389 | 1612 |  | 57 0 | 5.0 | 8.57 |  | 70 | 20 |
| 1845 | 2157 | 2375 | 1598 |  | 570 | 4 0 | 8.78 |  | 70 | 20 |
| 1900 | 2142 | 2368 | 1583 |  | 570 | 4.5 | 8.99 |  | 70 | 20 |
| 1915 | 2129 | 2365 | 1564 |  | 570 | 5.0 | 8.78 |  | 70 | 20 |
| 1930 | 2151 | 2392 | 1603 |  | 56.5 | 5.5 | 8.78 |  | 70 | 21 |
| 1945 | 2128 | 2372 | 1577 |  | 56.5 | 5.5 | 9.41 |  | 70 | 20 |
| 2000 | 2114 | 2360 | 1589 |  | 57.0 | 6.0 | 9.41 |  | 70 | 20 |
| 2015 | 2111 | 2367 | 1602 |  | 56.5 | 5.5 | 9.41 |  | 70 | 20 |
| 2030 | 2128 | 2407 | 1603 |  | 56.0 | 5.5 | 8.78 |  | 70 | 20 |
| 2045* | 2180 | 2441 | 1621 |  | 56.0 | 5.0 | 8.57 |  | 70 | 20 |
| 2100 | 2203 | 2368 | 1423 |  | 56.0 | 4.5 | 9.41 |  | 70 | 20 |
| 2115 | 2190 | 2336 | 1363 |  | 56.0 | 5.5 | 9.20 |  | 70 | 20 |

* 2050 HRS = off PCB fuel; purge out lines, etc with background
fuel and purge out for 1/2 hour; burnt 4150 gals of PCB's (mixture)
out of T-27 during this test

page #1

TRIAL TEST OF LIQUID PCB INCINERATION

BY: ROLLINS ENVIRONMENTAL SERVICES (TX), INC.

1030 HRS = on PCB's flow
1034 HRS = off PCB's; trip out on temp.
1042 HRS = back on PCB's flow.

DATE 11/14/1979
RUN # 3 (PCB's & Background fuel)

| TIME HOURS | TEMPERATURES (°F) |  |  |  |  | MONITORS |  |  | FANS (%) OPENED |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Hot duct | Afterburner | Kiln | Stack | Ambient | CO (PPM) | $O_2$ (%) | $CO_2$ (%) | Forced air | ID |
| 1045 | 2097 | 2448 | 1403 |  | 60.0 | 14.0 | 7.11 |  | 70 | 18 |
| 1100 | 2171 | 2462 | 1618 |  | 60.0 | 14.0 | 7.32 |  | 70 | 18 |
| 1115 | 2197 | 2480 | 1620 |  | 60.0 | 12.0 | 7.32 |  | 70 | 19 |
| 1130 | 2188 | 2449 | 1613 |  | 61.0 | 11.0 | 7.73 |  | 70 | 19 |
| 1145 | 2188 | 2459 | 1608 |  | 61.5 | 11.0 | 7.32 |  | 70 | 19 |
| 1200 | 2197 | 2450 | 1617 |  | 61.5 | 11.5 | 7.73 |  | 70 | 19 |
| 1215 | 2198 | 2441 | 1592 |  | 61.5 | 11.0 | 7.84 |  | 70 | 19 |
| 1230 | 2193 | 2442 | 1625 |  | 61.5 | 11.0 | 7.84 |  | 70 | 18 |
| 1245 | 2188 | 2435 | 1573 |  | 61.0 | 10.5 | 8.15 |  | 70 | 18 |
| 1300 | 2197 | 2440 | 1597 |  | 61.5 | 11.0 | 8.15 |  | 70 | 19 |
| 1315 | 2199 | 2435 | 1589 |  | 62.0 | 10.0 | 7.94 |  | 70 | 19 |
| 1330 | 2182 | 2416 | 1580 |  | 62.0 | 9.0 | 8.15 |  | 70 | 19 |
| 1345 | 2213 | 2424 | 1610 |  | 62.0 | 9.0 | 8.36 |  | 70 | 20 |
| 1400 | 2183 | 2368 | 1604 |  | 62.5 | 10.5 | 9.41 |  | 70 | 22 |
| 1415 | 2153 | 2319 | 1579 |  | 62.0 | 11.0 | 9.82 |  | 70 | 22 |

# TRIAL TEST OF LIQUID PCB INCINERATION

BY: ROLLINS ENVIRONMENTAL SERVICES (TX), INC.

page#2

DATE 11/14/1979
RUN # 3 (PCB's + Background Fuel)

| TIME HOURS | TEMPERATURES (°F) |  |  |  |  | MONITORS |  |  | FANS (%) OPENED |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Hot duct | Afterburner | Kiln | Stack | Ambient | CO (PPM) | $O_2$ (%) | $CO_2$ (%) | Forced air | ID |
| 1430 | 2145 | 2323 | 1613 |  | 61.5 | 9.75 | 9.61 |  | 70 | 21 |
| 1445 | 2144 | 2326 | 1617 |  | 60.0 | 9.5 | 9.82 |  | 70 | 22 |
| 1500 | 2154 | 2331 | 1624 |  | 62.0 | 9.5 | 9.41 |  | 70 | 22 |
| 1515 | 2156 | 2343 | 1618 |  | 62.5 | 9.0 | 9.82 |  | 70 | 22 |
| 1530 | 2144 | 2331 | 1562 |  | 63.0 | 7.0 | 10.66 |  | 70 | 23 |
| 1545 | 2140 | 2322 | 1541 |  | 63.0 | 8.0 | 10.45 |  | 70 | 22 |
| 1600 | 2151 | 2341 | 1672 |  | 63.0 | 9.0 | 10.66 |  | 70 | 22 |
| 1615 | 2141 | 2332 | 1549 |  | 63.0 | 9.0 | 11.91 |  | 70 | 22 |
| 1630 | 2147 | 2333 | 1646 |  | 63.0 | 9.0 | 10.87 |  | 70 | 22 |
| 1645 | 2141 | 2316 | 1697 |  | 63.0 | 9.0 | 10.24 |  | 70 | 22 |
| 1700* | 2169 | 2380 | 1629 |  | 62.0 | 9.0 | 9.82 |  | 70 | 22 |
| 1715 | 2115 | 2409 | 1612 |  | 62.0 | 8.0 | 8.36 |  | 70 | 23 |
| 1730 | 2191 | 2445 | 1602 |  | 61.0 | 7.0 | 8.98 |  | 70 | 23 |

* 1708 = off PCB fuel feed, switch over to background fuel and purge for 30 min.

page #1.

# TRIAL TEST OF LIQUID PCB INCINERATION

BY: ROLLINS ENVIRONMENTAL SERVICES (TX), INC.

1750 Hrs - PCB's flow initiated

DATE 11/15/1979
RUN # 4 (PCB's + Background Fuel)

| TIME HOURS | TEMPERATURES (°F) |  |  |  |  | MONITORS |  |  | FANS (%) OPENED |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Hot duct | Afterburner | Kiln | Stack | Ambient | CO (PPM) | $O_2$ (%) | $CO_2$ (%) | Forced air | ID |
| 1800 | 2119 | 2518 | 1510 |  | 59.0 | 2.5 | 7.73 |  | 68 | 30 |
| 1815 | 2175 | 2523 | 1703 |  | 59.0 | 4.0 | 7.72 |  | 68 | 30 |
| 1830 | 2195 | 2545 | 1740 |  | 59.0 | 6.0 | 8.56 |  | 68 | 30 |
| 1845 | 2205 | 2498 | 1749 |  | 58.5 | 6.0 | 8.56 |  | 68 | 30 |
| 1900 | 2140 | 2392 | 1753 |  | 58.0 | 5.0 | 8.78 |  | 68 | 30 |
| 1915 | 2202 | 2595 | 1691 |  | 58.0 | 6.0 | 7.32 |  | 68 | 30 |
| 1930 | 2201 | 2510 | 1714 |  | 57.5 | 6.0 | 8.56 |  | 68 | 30 |
| 1945 | 2197 | 2478 | 1740 |  | 57.0 | 5.0 | 8.78 |  | 68 | 30 |
| 2000 | 2099 | 2428 | 1346 |  | 57.0 | 4.0 | 8.78 |  | 68 | 30 |
| 2015 | 2172 | 2461 | 1782 |  | 56.5 | 3.0 | 8.78 |  | 68 | 30 |
| 2030 | 2160 | 2433 | 1803 |  | 56.5 | 4.0 | 9.41 |  | 68 | 30 |
| 2045 | 2165 | 2486 | 1735 |  | 56.0 | 5.0 | 8.56 |  | 68 | 30 |
| 2100 | 2182 | 2469 | 1726 |  | 56.0 | 6.0 | 9.00 |  | 68 | 30 |
| 2115 | 2123 | 2397 | 1521 |  | 56.0 | 5.5 | 9.41 |  | 68 | 30 |
| 2130 | 2122 | 2399 | 1631 |  | 56.0 | 5.0 | 9.00 |  | 68 | 30 |
| 2145 | 2131 | 2419 | 1811 |  | 56.0 | 5.5 | 8.78 |  | 68 | 30 |

page #2

# TRIAL TEST OF LIQUID PCB INCINERATION

BY: ROLLINS ENVIRONMENTAL SERVICES (TX), INC.

*2212 = off PCB's (low $O_2$)
slug/plug in kiln
□ 2227 = on PCB's - full feed

DATE 11/15/79
RUN # 4 (PCB's + Background Fuel)

| TIME HOURS | TEMPERATURES (°F) Hot duct | Afterburner | Kiln | Stack | Ambient | MONITORS CO (PPM) | $O_2$ (%) | $CO_2$ (%) | FANS (%) OPENED Forced air | ID |
|---|---|---|---|---|---|---|---|---|---|---|
| 2200 | 2140 | 2380 | 1669 | | 56.0 | 5.0 | 10.03 | | 68 | 28 |
| 2215* | 2135 | 2523 | 1672 | | 55.5 | 4.0 | 10.87 | | 68 | 27 |
| 2238 □ | 2329 | 2534 | 1381 | | 55.0 | 100+ | 7.82 | | 68 | 26 |
| 2245 | 2155 | 2285 | 1350 | | 55.0 | 5.0 | 11.29 | | 68 | 25 |
| 2300 | 2138 | 2291 | 1467 | | 55.0 | 6.0 | 8.78 | | 71 | 25 |
| 2315 | 2201 | 2372 | 1412 | | 56.0 | 6.5 | 10.00 | | 71 | 25 |
| 2330 | 2122 | 2286 | 1537 | | 55.5 | 5.5 | 10.66 | | 71 | 26 |
| 2345 | 2227 | 2419 | 1439 | | 55.0 | 7.0 | 8.57 | | 72 | 25 |
| 2400 | 2194 | 2338 | 1401 | | 55.0 | 6.0 | 9.82 | | 72 | 25 |
| 2415 | 2168 | 2295 | 1348 | | 56.0 | 5.5 | 10.24 | | 72 | 25 |
| 2430 | 2161 | 2291 | 1347 | | 56.0 | 5.0 | 10.24 | | 72 | 25 |
| 2445 | 2149 | 2286 | 1328 | | 56.0 | 5.0 | 10.45 | | 72 | 25 |
| 0100 | 2146 | 2279 | 1308 | | 55.0 | 6.5 | 10.24 | | 72 | 25 |
| | | | | | | | | | | |
| | | | | | | | | | | |

# APPENDIX II

United States
Environmental Protection
Agency

Region 6
1201 Elm Street
Dallas TX 75270

Arkansas, Louisiana,
Oklahoma, Texas,
New Mexico

EPA

RECEIVED NOV 30 1978

November 22, 1978

Mr. Jerry Neel, Vice President
Rollins Environmental Services, Inc.
P.O. Box 609
Deer Park, Texas 77536

Dear Mr. Neel:

This letter is in response to your general intentions letter of September 1, 1978 in which you proposed not to purchase and install a continuous carbon dioxide ($CO_2$) analyzer for use during PCB incineration.

My staff has reviewed the relative merits of your request based on the incinerator's design and prior combustion experience. This alternative proposal is submitted for your consideration. Periodic monitoring of $CO_2$ and a higher combustion efficiency of 99.9% during PCB incineration would be substituted for continuous $CO_2$ monitoring. EPA Region 6 would retain the right to require continuous $CO_2$ monitoring in the future if conditions warranted this.

A formal reply from Rollins is necessary if you accept this alternative.

Sincerely,

Adlene Harrison

Adlene Harrison
Regional Administrator

cc: John Rollins, Jr.
Rollins Environmental Services, Inc.

W. B. Philipbar
Rollins Environmental Services, Inc.

Matt Straus
Office of Solid Waste (WH-562)

Jack Carmichael
Texas Department of Health

Jay Snow
Texas Department of Water Resources

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COPY

Rollins

Services (TX) Inc.

February 5, 1979

Ms. Adlene Harrison
Regional Administrator
Region VI
U.S. Environmental Protection Agency
1201 Elm Street
Dallas, Texas 75270

Dear Ms. Harrison:

This letter is in response to your letter of November 22, 1978, in which you submitted an alternate proposal for continuous $CO_2$ monitoring of our incinerator during PCB disposal.

Having reviewed your proposal, we accept your alternative and will perform periodic monitoring of $CO_2$ and maintain a combustion efficiency of 99.9% during PCB incineration.

Thank you for your consideration in eliminating the requirement for continuous $CO_2$ monitoring. Our PCB test proposal will be mailed this week, and we look forward to your staff's reply so that we may proceed with an incinerator test as soon as possible.

Sincerely,

ROLLINS ENVIRONMENTAL SERVICES (TX) INC.

Jerry D. Neel

Jerry D. Neel
Vice President

JDN/rw

cc: Mr. Matt Strauss, E.P.A.
Mr. Bill Stewart, T.A.C.B.
Mr. Jay Snow, T.D.W.R.
Mr. W. B. Philipbar, Jr., R.E.S.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VI
6608 Hornwood Drive
Houston, Texas 77074

16 NOV 1979

Ms. Dianne Cass
Chemist
NUS Corporation
900 Gemini Avenue
Houston, Texas 77058

Dear Ms. Cass:

I have received your report of analysis of quality assurance samples for PCB content which I supplied to you in October 1979. The following are the results reported by you and the expected true values of the samples supplied to you.

Sample No. 1 - Reported Composition:

Aroclor 1254; 2 ug/liter (ppb)

Expected Actual Composition:

Aroclor 1254; 4.8 ug/liter (ppb)

Sample No. 2 - Reported Composition:

Aroclor 1016; 2 ug/liter (ppb)

Expected True Composition:

Aroclor 1016; 3.2 ug/liter (ppb)

Your PCB specie identifications were correct in each instance, and I have determined that you quantitative values would be within the range of acceptability based on similar type samples analyzed annually by State and Federal laboratories for proficiency evaluation.

Sincerely,

William D. Langley

William D. Langley, Ph.D.
Chief, Laboratory Section

cc:
Oscar Ramirez, Jr., 6ASA
Charles Gazda, 6ASASC

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NUS CORPORATION
CYRUS WM. RICE DIVISION

SOUTH CENTRAL OPERATIONS
900 GEMINI AVENUE
HOUSTON, TEXAS 77058
713-488-1810

C-30-00-02/80-010

February 13, 1980

Mr. Doug Cooper
Rollins Environmental Services
P.O. Box 609
Deer Park, Texas 77536

Dear Mr. Cooper:

After reviewing the chemical literature and talking to several people engaged in research in the determination of chlorinated dibenzofurans in environmental samples, we have regretfully come to the conclusion that no reliable widely accepted procedure for determining trace amounts of "total" chlorinated dibenzofurans exists at the present time. This conclusion was reached for the following reasons:

1. Of the numerous polychlorinated bizenzofuran derivatives theoretically existing only three are commercially available.

2. No procedure for definitely isolating trace amounts of chlorinated dibenzofurans from polychlorinated biphenyls was found.

3. The aqueous samples analyzed typically contained less than <0.001 mg/liter total PCB. If the original polychlorinated biphenyl used in the test contained chlorinated dibenzofurans in only trace quantities as is reported in the chemical literature, there is little likelihood that chlorinated dibenzofurans would be present in the solutions in measureable amounts.

If additional information is required, please call.

Sincerely,

Jerry W. Bright
Jerry W. Bright
Analytical Laboratory Manager

/ss

# APPENDIX III

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## Appendix III

## MASS FLOW RATE OF FLUE GAS

The maximum combined horsepower of the two induced draft fans, operating in series, is 900. From the composite fan performance curve, Figure12, the rated capacity is 81,000 cu ft/min of gas at 170°F and a density of 0.0472 lb/cu ft.

$$\text{The fan capacity} = \frac{81{,}000 \text{ cu ft/min}}{60 \text{ sec/min}} \times 0.0472 \text{ lbs/cu ft} = 63.72 \text{ lbs/sec.}$$

The scrubber cools the flue gas by adiabatic humidfication and the exhaust gas at 170 °F is saturated with 0.4327 lb water for each pound of dry gas. Therefore, the fans move

$$63.72 \text{ lbs/sec} \times \frac{1}{1.4327} = 44.48 \text{ lbs/sec dry gas}$$

Since very small quantities of water are produced by combustion of highly chlorinated hydrocarbons, the quantity of gas moving thru the hot zone is 44.5 lbs/sec.

The density of the gas calculated by the formula(8)

$$\frac{520\ ^\circ R}{(13.1)(x\ ^\circ R)} = \underline{\text{lbs}}/\text{cu ft}$$

where x is the temperature of the gas, is 0.0151 lbs/cu ft at a temperature of 1223 °C.

## AVERAGE RESIDENCE TIME

| | |
|---|---|
| Volume of Loddby chamber | 491 cu ft |
| Volume of afterburner | 6285 cu ft |
| Volume of hot duct | 1700 cu ft |
| | 8476 cu ft |

Test No 1 (background) at 2763 °R:

$$\frac{520\ ^\circ\mathrm{R}}{(13.1)(2763\ ^\circ\mathrm{R})} = 0.0144\ \mathrm{lb/cu\ ft}$$

$$\frac{(0.0144\ \mathrm{lb/cu\ ft})(8476\ \mathrm{cu\ ft})}{(44.48\ \mathrm{lb/sec})} = 2.74\ \mathrm{secs.}$$

Test No 2 at 2796 °R:

$$\frac{520\ ^\circ\mathrm{R}}{(13.1)(2796\ ^\circ\mathrm{R})} = 0.0142\ \mathrm{lb/cu\ ft}$$

$$\frac{(0.0142\ \mathrm{lb/cu\ ft})(8476\ \mathrm{cu\ ft})}{(44.48\ \mathrm{lb/sec})} = 2.71\ \mathrm{secs.}$$

Test No 3 at 2853 °R:

$$\frac{520\ ^\circ\mathrm{R}}{(13.1)(2853\ ^\circ\mathrm{R})} = 0.0139\ \mathrm{lb/cu\ ft}$$

$$\frac{(0.0139\ \mathrm{lb/cu\ ft})(8476\ \mathrm{cu\ ft})}{(44.48\ \mathrm{lb/sec})} = 2.65\ \mathrm{secs.}$$

Test No 4 at 2870 °R:

$$\frac{520\ ^\circ\mathrm{R}}{(13.1)(2870\ ^\circ\mathrm{R})} = 0.0138\ \mathrm{lb/cu\ ft}$$

$$\frac{(0.0138\ \mathrm{lb/cu\ ft})(8476\ \mathrm{cu\ ft})}{(44.48\ \mathrm{lb/sec})} = 2.63\ \mathrm{secs.}$$

# APPENDIX IV

SOUTHERN PETROLEUM LABORATORIES, INC.

P.O. BOX 20807
HOUSTON, TEXAS 77025
(713) 668-4448

P.O. BOX 52768
LAFAYETTE, LOUISIANA 70501
(318) 984-2374

Certificate of Analysis No. 78196-78199

Company: Rollins Environmental Service
Sample of: Test 1,2,3,4

For: Rollins Environmental Service
P O Box 609
Deer Park, Texas 77536

Invoice No. 89621

December 31, 1979

Attn: Douglas Cooper

---

| SPL# | 78196 | 78197 | 78198 | 78199 |
|---|---|---|---|---|
| Rollin # | test 3 | test 2 | test 1 | test 4 |
| Carbon | 50.94% | 48.58% | 63.65% | 50.44% |
| Hydrogen | 4.73% | 4.66% | 8.86% | 4.80% |
| S | 0.035% | 0.036% | 0.072% | 0.034% |
| Sulfur | - - - - too much Cl interference - - - - - | | | |
| Chloride | 54.3 | 43.8 | 24.2 | 56.3 |
| Nitrogen | 0.015wt% | 0.027wt% | 0.072wt% | 0.016wt% |

Southern Petroleum Laboratories, Inc.

By JC Winfrey
J.C. Winfrey

# APPENDIX V

NUS CORPORATION

ANALYTICAL SERVICES LABORATORY
SOUTH CENTRAL OPERATIONS
900 GEMINI AVENUE • HOUSTON, TEXAS 77058
713-488-1810

Rollins Environmental Services, Inc.
Industrial Waste Disposal
P.O. Box 609
Deer Park, Texas 77536

Attn: Doug Cooper

Client No. 0
Date Sampled 11/9/79
Date Received 11/9/79
Date Reported 11/14/79

Composite sample of PCB material in T-27

| NUS Sample No. | |
|---|---|
| 29110127 | Total PCB* 470,000 mg/kg<br>Specific Gravity 1.340 |

**Special Instructions** This sample was received in a plastic bottle with a waxed paper liner.

*Although individual isomers were not identified, it appeared that a predominance of PCB 1254 and PCB 1260 existed.

Test results reported in mg/liter unless otherwise noted

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NUS
CORPORATION

ANALYTICAL SERVICES LABORATORY
SOUTH CENTRAL OPERATIONS
900 GEMINI AVENUE • HOUSTON, TEXAS 77058
713-488-1810

Rollins Environmental Services, Inc.
Industrial Waste Disposal
P.O. Box 609
Deer Park, Tx 77536
Attn: Doug Cooper

**Client No.** Q
**Date Sampled** 11/12, 13, ?, 15/79
**Date Received** 11/13,14,15,16/79
**Date Reported** 11/20/79

| NUS Sample No. | | |
|---|---|---|
| 29110165 | Test 1 Fuel Composite 1 | Total PCB <1 mg/kg |
| 29110166 | Test 1 Fuel Composite 2 | Total PCB <1 mg/kg |
| 29110167 | Test 1 Fuel Composite 3 | Total PCB <1 mg/kg |
| 29110183 | Test 2 Fuel Composite 1 | Total PCB 330,000 mg/kg |
| 29110184 | Test 2 Fuel Composite 2 | Total PCB 380,000 mg/kg |
| 29110185 | Test 2 Fuel Composite 3 | Total PCB 380,000 mg/kg |
| 29110229 | Test 3 Fuel Composite 1 | Total PCB 360,000 mg/kg |
| 29110230 | Test 3 Fuel Composite 2 | Total PCB 380,000 mg/kg |
| 29110231 | Test 3 Fuel Composite 3 | Total PCB 360,000 mg/kg |
| 29110306 | Test 4 Fuel Composite 18:00 to 19:45 | Total PCB 325,000 mg/kg |
| 29110305 | Test 4 Fuel Composite 20:00 to 12:45 | Total PCB 340,000 mg/kg |
| 29110307 | Test 4 Fuel Composite 22:00 to 23:45 | Total PCB 310,000 mg/kg |
| 29110308 | Test 4 Fuel Composite 24:00 to 01:08 | Total PCB 310,000 mg/kg |

**Special Instructions**

Test results reported in mg/liter unless otherwise noted

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NUS CORPORATION

ANALYTICAL SERVICES LABORATORY
SOUTH CENTRAL OPERATIONS
900 GEMINI AVENUE • HOUSTON, TEXAS 77058
713-488-1810

Rollins Environmental Services, Inc.
Industrial Waste Disposal
P.O. Box 609
Deer Park, Tx 77536

Attn: Doug Cooper

**Client No.** 0
**Date Sampled** 11/12/79
**Date Received** 11/13/79
**Date Reported** 11/20/79

| NUS Sample No. | Test No. 1 | |
|---|---|---|
| 29110171 | Well Sample No. 1 (BT) | Total PCB <0.001 mg/1 |
| 29110172 | Well Sample No. 2 (BT) | Total PCB <0.001 mg/1 |
| 29110173 | Well Sample No. 3 (BT) | Total PCB <0.001 mg/1 |
| 29110174 | Lime Slurry Composite #1 | Total PCB <0.001 mg/1 |
| 29110175 | Lime Slurry Composite #2 | Total PCB <0.001 mg/1 |
| 29110176 | Lime Slurry Composite #3 | Total PCB <0.001 mg/1 |
| 29110162 | Scrub water at TUT #1 | Total PCB <0.001 mg/1 |
| 29110163 | Scrub water at TUT #2 | Total PCB <0.001 mg/1 |
| 29110164 | Scrub water at TUT #3 | Total PCB <0.001 mg/1 |
| 29110168 | F-4 Recirculated Composite #1 | Total PCB <0.001 mg/1 |
| 29110169 | F-4 Recirculated Composite #2 | Total PCB <0.001 mg/1 |
| 29110170 | F-4 Recirculated Composite #3 | Total PCB <0.001 mg/1 |

**Special Instructions**

Test results reported in mg/liter unless otherwise noted

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NUS CORPORATION

ANALYTICAL SERVICES LABORATORY
SOUTH CENTRAL OPERATIONS
900 GEMINI AVENUE • HOUSTON, TEXAS 77058
713-488-1810

Rollins Environmental Services, Inc.
Industrial Waste Disposal
P.O. Box 609
Deer Park, Tx 77536
Attn: Doug Cooper

Client No. 0
Date Sampled 11/13/79
Date Received 11/14/79
Date Reported 11/20/79

| NUS Sample No. | Test No. 2 | |
|---|---|---|
| 29110186 | Well No. 1 | Total PCB <0.001 mg/1 |
| 29110187 | Well No. 2 | Total PCB <0.001 mg/1 |
| 29110188 | Well No. 3 | Total PCB <0.001 mg/1 |
| 29110180 | LS-305 Sample #1-4 | Total PCB 0.001 mg/1 |
| 29110181 | LS-305 Sample #5-8 | Total PCB <0.001 mg/1 |
| 29110182 | LS-305 Sample #9-12 | Total PCB 0.004 mg/1 |
| 29110189 | TUT No. 1 | Total PCB 0.001 mg/1 |
| 29110190 | TUT No. 2 | Total PCB <0.001 mg/1 |
| 29110191 | TUT No. 3 | Total PCB 0.001 mg/1 |
| 29110192 | F-4 No. 1 | Total PCB 0.002 mg/1 |
| 29110193 | F-4 No. 2 | Total PCB <0.001 mg/1 |
| 29110194 | F-4 No. 3 | Total PCB <0.001 mg/1 |

Special Instructions

*Test results reported in mg/liter unless otherwise noted*

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NUS CORPORATION

ANALYTICAL SERVICES LABORATORY
SOUTH CENTRAL OPERATIONS
900 GEMINI AVENUE • HOUSTON, TEXAS 77058
713-488-1810

Rollins Environmental Services, Inc.
Industrial Waste Disposal
P.O. Box 609
Deer Park, Tx 77536

Attn: Doug Cooper

**Client No.** 0
**Date Sampled** 11/14/79
**Date Received** 11/15/79 and 11/16/79
**Date Reported** 11/20/79

| **NUS Sample No.** | Test 3 | |
|---|---|---|
| 29110221 | Well Sample No. 1 | Total PCB <0.001 mg/1 |
| 29110222 | Well Sample No. 2 | Total PCB 0.001 mg/1 |
| 29110223 | Well Sample No. 3 | Total PCB <0.001 mg/1 |
| 29110291 | TUT Sample 1 | Total PCB <0.001 mg/1 |
| 29110227 | TUT Sample 2 | Total PCB 0.002 mg/1 |
| 29110228 | TUT Sample 3 | Total PCB 0.001 mg/1 |
| 29110224 | F4 Sample 1 | Total PCB <0.001 mg/1 |
| 29110225 | F4 Sample 2 | Total PCB 0.001 mg/1 |
| 29110226 | F4 Sample 3 | Total PCB <0.001 mg/1 |
| 29110232 | 305 L.S. Composite 1-4 | Total PCB 0.001 mg/1 |
| 29110233 | 305 L.S. Composite 5-8 | Total PCB 0.001 mg/1 |
| 29110234 | 305 L.S. Composite 9-14 | (Sample accidently destroyed) |

**Special Instructions**

Test results reported in mg/liter unless otherwise noted

NUS CORPORATION

ANALYTICAL SERVICES LABORATORY
SOUTH CENTRAL OPERATIONS
900 GEMINI AVENUE • HOUSTON, TEXAS 77058
713-488-1810

Rollins Environmental Services, Inc.
Industrial Waste Disposal
P.O. Box 609
Deer Park, Tx 77536
Attn: Doug Cooper

**Client No.** 0
**Date Sampled** 11/15/79
**Date Received** 11/16/79
**Date Reported** 11/20/79

| NUS Sample No. | | |
|---|---|---|
| | Test 4 | |
| 29110292 | Well Sample 1 | Total PCB <0.001 mg/l |
| 29110293 | Well Sample 2 | Total PCB 0.002 mg/l |
| 29110294 | Well Sample 3 | Total PCB 0.001 mg/l |
| 29110295 | Well Sample 4 | Total PCB 0.001 mg/l |
| 29110296 | F4 Sample 1 | Total PCB <0.001 mg/l |
| 29110297 | F4 Sample 2 | Total PCB 0.001 mg/l |
| 29110298 | F4 Sample 3 | Total PCB 0.001 mg/l |
| 29110299 | F4 Sample 4 | Total PCB <0.001 mg/l |
| 29110300 | TUT 1 | Total PCB 0.001 mg/l |
| 29110301 | TUT 2 | Total PCB <0.001 mg/l |
| 29110302 | TUT 3 | Total PCB 0.001 mg/l |
| 29110303 | TUT 4 | Total PCB 0.002 mg/l |
| 29110304 | TUT 5 (duplicate) | Total PCB 0.002 mg/l |
| 29110309 | Lime (Composite of 1-4) | Total PCB <0.001 mg/l |
| 29110310 | Lime (Composite of 5-8) | Total PCB 0.002 mg/l |
| 29110311 | Lime (Composite of 9-12) | Total PCB 0.002 mg/l |
| 29110312 | Lime (Composite of 13-15) | Total PCB 0.001 mg/l |

**Special Instructions**

Test results reported in mg/liter unless otherwise noted

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NUS CORPORATION

ANALYTICAL SERVICES LABORATORY
SOUTH CENTRAL OPERATIONS
900 GEMINI AVENUE • HOUSTON, TEXAS 77058
713-488-1810

Rollins Environmental Services, Inc.
Industrial Waste Disposal
P.O. Box 609
Deer Park, Tx 77536
Attn: Doug Cooper

Client No. 0
Date Sampled 11/16/79
Date Received 11/17/79
Date Reported 11/20/79

| NUS Sample No. | | |
|---|---|---|
| 29110326 | T 27 Flush (last purge - 1st of 3 samples) | Total PCB <1 mg/kg |
| 29110327 | T 27 Flush (Final Rinse- 2nd of 3 samples) | Total PCB <1 mg/kg |
| 29110328 | T 27 Flush (Final 15,000 Gal. Flush - 3rd of 3 samples) | Total PCB <1 mg/kg |

Special Instructions

Test results reported in mg/liter unless otherwise noted

# Division 3

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# EMISSIONS TESTING DURING INCINERATION OF PCBs AT ROLLINS ENVIRONMENTAL SERVICES, INC., DEER PARK, TEXAS

SEPTEMBER 1981

by

T. L. Sarro, D. R. Moore, and D. G. Ackerman
TRW Inc., Environmental Engineering Division
One Space Park
Redondo Beach, Ca. 90278

EPA Contract No. 68-02-3174, Work Assignment 56
EPA Program Element No. C1YL1B

Program Manager: Alice C. Gagnon
Industrial Environmental Research Laboratory
Office of Environmental Engineering and Technology
Research Triangle Park, NC 27711

Task Officer: Philip C. Schwindt
U.S. Environmental Protection Agency
Region 6 Office
Dallas, TX. 75270

Prepared for:

U. S. Environmental Protection Agency
Office of Pesticides and Toxic Substances and
Region 6 Office
Washington, D. C. 20460

## DISCLAIMER

This report has been reviewed by the Region 6 Office, Office of Toxic Substances, and the Industrial Environmental Research Laboratory, U. S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U. S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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## ABSTRACT

This report describes the emissions testing performed and results obtained from Rollins Environmental Services, Inc., Deer Park, Texas, while polychlorinated biphenyls (PCBs) were being incinerated.

Samples were taken of all incineration system influent and effluent streams, including stack gas, PCBs fed, auxiliary fuel and waste, scrubber input, scrubber output, and treated plant effluent. Stack gas samples were taken with a modified Method 5 Train incorporating a porous polymer adsorbent and operating isokinetically. Samples of other streams were taken manually at specified intervals. Incineration system operating data also were acquired.

This report was submitted in fulfillment of Contract No. 68-02-3174, Work Assignment 56, by TRW Inc., Environmental Engineering Division, under sponsorship of the U. S. Environmental Protection Agency. This report covers the period July 15, 1980 to September 15, 1980 (when the testing was performed) and January 26, 1981 to February 26, 1981, and work was completed as of February 26, 1981.

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## ACKNOWLEDGEMENTS

The authors gratefully acknowledge the contributions of Mr. R. W. Korner, Mr. M. Drehsen, and Mrs. B. L. Riley to this report.

The authors also gratefully acknowledge the contribution of the members of the field sampling team to this project. Team members were: Mr. D. R. Moore, Team Leader, Mr. T. L. Sarro, Field Engineer, Mr. W. F. Wright, Mr. R. W. Korner, Mr. C. W. Stackhouse, Mr. E. P. Banks, Mr. J. O. Berger, Mr. J. McReynolds, and Mr. M. Apoian.

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# 1. INTRODUCTION

TRW Inc., Environmental Engineering Division, under contract to the U.S. Environmental Protection Agency (Contract No. 68-02-3174, Work Assignment No. 31), performed emissions testing during incineration of polychlorbiphenyls (PCBs) at Rollins Environmental Services, Inc., Deer Park, Texas. The purpose of the testing was to determine whether or not polychlorinated dibenzo-p-dioxins (PCDDs) and/or polychlorinated dibenzofurans were emitted from the incineration system while PCBs were being incinerated.

Technical direction of the sampling effort was provided by the U.S. Environmental Protection Agency's (EPA) Region 6 Office in Dallas, Texas. Mr. Philip C. Schwindt of Region 6 was the Technical Officer for this work assignment. Technical content of this effort was coordinated with the following organizations:

- EPA's Office of Pesticides and Toxic Substances, Washington, D.C., Mr. Bill Gunter, Mr. Glenn Kuntz, and Dr. Don Barnes.
- EPA's Special Pesticide Review Division, Arlington, VA, Mr. Mike Dellarco.
- EPA's Health Effects Research Laboratory, Research Triangle Park, NC, Dr. Bob Harless, Dr. Bob Lewis, and Mr. Merrill Jackson
- Wright State University's Brehm Laboratory, Dayton, OH, the analysis contractor, Dr. Tom Tiernan.
- Rollins Environmental Services, Deer Park, TX, Messrs. Dave Stang, Don Matter, Tracy Austin, and Jerry Neel.

At TRW, this effort was managed by Dr. Don Ackerman. Mr. Dave Moore was the field team leader, and Mr. Tom Sarro was the field engineer.

Samples were taken of all incineration system influent and effluent streams, including stack gas, PCB feeds (liquids only), auxiliary fuel and waste feeds, and scrubber inlet and outlet solutions. Testing was performed during the period 8-23 August 1980.

The following chapters and appendices of this report describe the testing performed and results obtained: Chapter 2, Summary; Chapter 3, Facility Descriptions; Chapter 4, Sampling and Monitoring, Chapter 5, Technical Problems and Recommendations; Appendix A, Gas Monitoring; Appendix B, Field Data; Appendix C, Process Data; Appendix D, Calibration Data; and Appendix E, Chain of Custody Forms.

# 2. SUMMARY

## 2.1 SAMPLING

The field test activity took place at Rollins Environmental Services during the time frame of August 4, 1980 through August 22, 1980. The third test was postponed in August because of Hurricane Allen, and this third test was conducted from August 20 through August 22, 1980. All required tests were completed, and all recovered samples were sent to Wright State University for analysis.

Duplicate stack gas samples were taken during incineration of three different fuel types. The test conditions were as follows:

Test 1 - Incineration of liquid waste at normal incineration burn fuel rates and temperatures.

Test 2 - Incineration of PCB/liquid waste blend at normal fuel feed rates but at elevated temperature of 1200± 100°C, $O_2$ level greater than 3%, and a CO content of less than 80 ppm.

Test 3 - Incineration of PCB blended with fuel oil and the incinerator operating as in test number 2.

A daily field test summary is presented in Table 1. A summary of the reduced data on a daily basis as calculated from field data sheets is presented in Table 2. Data listed in Table 2 have been corrected to standard conditions of 20°C and a barometric pressure of 760 mm Hg (1 atmosphere). Tables 3 and 4 are a summation of the gaseous and liquid samples collected and their respective sampling frequencies.

Appendix A presents details of combustion gas monitoring. Field data sheets are given in Appendix B. Appendix C contains all process data, while Appendix D is the calibration data. Appendix E contains the Chain of Custody reports.

TABLE 1. DAILY TEST SUMMARY AT ROLLINS ENVIRONMENTAL SERVICES

| Date (1980) | Test No. | Sampling Locations | Test Comments |
|---|---|---|---|
| 8/4 | 0 | Outlet | Preliminary measurements |
| 8/5 | 1 | Outlet - Train 1 | Test started at 1320 hours. Resin trap plugged and impinger filled with condensate, train stopped at 1405 hours. Changed nozzle - restarted with new train at 1650 hours - Resin plugged again. At 2110 hours train stopped. Test scrubbed. |
| | | Outlet - Train 2 | Test started at 1315 hours, stopped at 1407 to change impinger, restarted.at 1640 hours, and stopped 2104 hours due to continual resin trap plugging. Test scrubbed. |
| | | Inlet - $CO_2$ Sampling | 4 samples taken. Results are good. |
| | | Outlet - Gas Sampling | 1 composite sample. Results are good. |
| 8/6 | 2 | Outlet - Train 1 | Test started at 1505 hours. Removed cooling water from Florisil traps. Made resin trap changes due to plugging. Test quality is good. |
| | | Outlet - Train 2 | Test started at 1503 hours and ended at 2255 hours. Test quality is good. |
| | | Inlet - $CO_2$ Sampling | 8 samples taken. Test quality is good. |
| | | Outlet - Gas Sampling | 1st sample had leaks in sample line. Discarded result from calculations, 2 additional integrated samples taken. Results are good. |
| 8/7 | 3 | Outlet - Train 1 | Test started at 1420 hours. At 1800 hours train plugged at resin trap. Replaced XAD-2 trap and continued test. At 2107 hours, removed Florisil trap and replaced with empty one. Still plugging occurred. Punched holes in frits to assist flow. No help, frits were reddish brown, resin appeared clean. Test stopped at 202 minutes due to plugging. Test quality good. |

(continued)

TABLE 1. (Continued)

| Date (1980) | Test No. | Sampling Locations | Test Comments |
|---|---|---|---|
| | | Outlet - Train 2 | Test started at 1420 hours. Train plugged at 1432 hours. Replaced both traps. At 1736 hours removed Florisil trap. Replaced with empty trap, punched holes in frits. No help. Test stopped at 2248 hours due to plugging problem. Test quality is good. |
| | | Inlet - $CO_2$ Sampling | 13 samples taken. Test quality is good. |
| | | Outlet - Gas Sampling | 3 integrated samples taken. Test quality is good. |
| 8/22 | 4 | Outlet - Train 1 | Test started at 0750 hours - XAD-2 resin plugged at 1100 hours, replaced trap and finished test. Test quality is good. |
| | | Outlet - Train 2 | Test started at 0745 hours. No apparent resin plugging problem. Test quality is good. |
| | | Inlet - $CO_2$ Sampling | Sampling probe burned off near port opening - possible sampling of air. Used control room $CO_2$ readings. Test quality poor. |
| | | Outlet - Gas Sampling | 2 integrated samples taken. Test quality is good. |

## TABLE 2. DAILY DATA SUMMARY*

| DATE | Test Number | | DSCF+ | $Nm^3$# | $O_2$ % | $CO_2$ % | CO ppm | $N_2$ % | Stack Temp °F | Molecular Weight | Moisture % | Velocity ft/sec | Gas Flow ACFM | Gas Flow DSCFM | Isokinetic Rate,% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-6-80 | 1 | Train 1 | 99.472 | 2.8 | 14.5 | 4.5 | - | 81.0 | 162.1 | 25.99 | 29.30 | 35.58 | 60353.096 | 36242.759 | 103.8 |
| | | Train 2 | 96.919 | 2.7 | 14.5 | 4.4 | - | 81.0 | 162.6 | 25.89 | 30.21 | 36.58 | 62052.662 | 36753.550 | 98.9 |
| 8-7-80 | 2 | Train 1 | 77.232 | 2.2 | 13.9 | 4.3 | - | 81.8 | 165.2 | 25.41 | 34.12 | 36.71 | 62279.183 | 34672.041 | 99.3 |
| | | Train 2 | 78.251 | 2.2 | 13.9 | 4.3 | - | 81.8 | 165.7 | 25.48 | 33.54 | 35.98 | 61038.315 | 34253.612 | 98.0 |
| 8-22-80 | 3 | Train 1 | 92.882 | 2.6 | 11.6 | 7.3 | - | 81.2 | 158.1 | 26.21 | 29.37 | 36.75 | 62342.982 | 36679.587 | 99.9 |
| | | Train 2 | 94.713 | 2.7 | 11.6 | 7.3 | - | 81.2 | 156.8 | 26.23 | 29.24 | 35.61 | 60406.649 | 35680.825 | 108.4 |

*Where English units are used, they were provided by ENSCO.

+Dry standard cubic feed sampled, 20°C, 760 mm Hg.

#Normal cubic meters sampled, 20°C, 760 mm Hg.

TABLE 3. GASEOUS SAMPLING SCHEME

| Frequency | Sample Description | Sample for | Sampled by | Analyzed by |
|---|---|---|---|---|
| 4 hr | Stack gas | PCBs<br>PCDDs*<br>PCDFs** | TRW | Wright State University |
| Continuous | Stack gas | $O_2$ | Rollins | Rollins |
| Continuous | Stack gas | CO | Rollins | Rollins |
| 120 minutes | Stack Gas | $CO_2$<br>$O_2$ | TRW | TRW (GC) |
| 30 minutes | Hot Duct | $CO_2$<br>$O_2$ | TRW | TRW (GC) |
| 30 minutes | Fuel | PCBs<br>PCDDS, PCDFS | Rollins/TRW | EPA Houston |
| 30 minute | Scrubber In | PCBs<br>PCDDs, PCDFs | TRW | Wright State University |
| 30 minute | Scrubber Out | PCBs<br>PCDDs, PCDFs | TRW | Wright State University |
| 30 minute | F-4 Outlet | PCBs<br>PCDDs, PCDFs | TRW | Wright State University |
| 30 minute | Well Water | PCB's<br>PCDDs, PCDFs | TRW | Wright State University |

*PCDDs = polychlorodibenzo-p-dioxins.
**PCDFs = polychlorodibenzofurans.

TABLE 4. LIQUID SAMPLING SCHEME

| Stream | Sampling Frequency | Total Samples 4-hour Test Period) | Sample Quantity* | Composite Storage Size/Type+ |
|---|---|---|---|---|
| • Liquid PCB Feed | 30 minutes | 8 | 250 ml per sample | Half-gallon amber glass |
| • Well Water Feed | 30 minutes | 8 | 250 ml per sample | Half-gallon amber glass |
| • Lime Slurry Feed | 30 minutes | 8 | 250 ml per sample | Half-gallon amber glass |
| • Touch Up Tank | 30 minutes | 8 | 250 ml per sample | Half-gallon amber glass |
| • Effleunt Discharge | 30 minutes | 8 | 250 ml per sample | Half-gallon amber glass |

*Duplicate samples to be collected from all streams.

+500 ml aliquot of composited PCB feed and touch-up tank to be removed from half-gallon composites and provided to R.E.S.

## 2.2 PROCESS MONITORING

Table 5 provides a summary of critical operating parameters of the incinerator for each of the three test days including means and standard deviations whenever appropriate. These parameters include hot duct temperatures, residence times, combustion efficiencies, waste feed rates, and concentrations of $CO_2$, CO, and $O_2$ in the flue gas. All of these are based on 15-minute observations except the waste feed rate which is based on volume measurements of waste at the beginning and end of each test. All $CO_2$ values were determined by gas chromatographic (GC) analysis of samples taken at the scrubber inlet. All CO values were read from a continuous monitor, The $O_2$ values were taken from a continuous monitor for Test 3, and by GC analysis for test two and three due to technical problems with the $O_2$ analyzer.

The CO values are all known to be too high, because the on-line CO monitor could be seen to drift upward during every test. Frequent recalibration kept the instrument within tolerable limits, but the means are still artificially high. This is important, because the combustion efficiencies in Table 5 were calculated using these values. The average CO level for the third test day was 6.1 ppm. Since this value is known to contain some instrument drift, and since every recalibration of the CO monitor revealed a CO concentration below 4 ppm, an average CO concentration below 5 ppm for any given test day seems reasonable. This corresponds to a combustion efficiency of 99.9929%, which is well above the 99.9% requirement set by EPA.

The waste feed rate given in Table 5 represents the volume flow of PCB waste. The PCB content of this flow is unknown pending laboratory analysis. These flows were calculated based on volume changes at the beginning and end of each test, and hence no standard deviations were calculated.

Table 6 presents the minimum and maximum values of selected parameters for each test. Also, the minima and maxima of these parameters during PCB mode operation are given. It is worth noting that while the incinerator was

TABLE 5. DAILY AVERAGES AND STANDARD DEVIATIONS OF COMBUSTION PARAMETERS

| Parameter | Test 1 (8-6-80) Background Fuel | | Test 2 (8-7-80) Liquid PCB & Background Fuel | | Test 3 (8-22-80) Liquid PCB & Fuel Oil | |
|---|---|---|---|---|---|---|
| | $\bar{x}^{*}$ | $s^{+}$ | $\bar{x}$ | $s^{+}$ | $\bar{x}$ | s |
| $CO_2$ (%) | 8.4 | 0.16 | 8.2 | 0.41 | 7.0 | + |
| CO (ppm) | 9.3# | 2.50 | 20.1# | 11.95 | 6.1# | 4.93 |
| $O_2$ (%) | 11.0(GC) | 0.32 | 10.5(GC) | 0.43 | 9.6(continuous) | 2.53 |
| Hot duct temperature | 2028°F | 12.17 | 2145°F | 29.40 | 2152°F | 26.70 |
| | 1109°C | - | 1174°C | - | 1178°C | - |
| Residence time (seconds) | 2.41 | 0.0384 | 2.28 | 0.1018 | 2.27 | 0.0443 |
| Waste feed rate | 0 | - | 7.48GPM | - | 9.51GPM | - |
| | 0 | - | 0.47 liters/sec | - | 0.60 liters/sec | - |
| Combustion efficiency | 99.9883 | 0.0023 | 99.9753 | 0.0137 | 99.9893 | 0.0071 |

$\bar{x}$ and s are, respectively, mean and standard deviation.
+ no standard deviation exists because there was only one observation of $CO_2$ for Test 3
# these means are too high due to drift of the CO monitor.

TABLE 6. DAILY MINIMUM AND MAXIMUM VALUES OF COMBUSTION PARAMETERS

| Parameter | Test 1 (8-6-80) Background Fuel | | Test 2 (8-7-80) Liquid PCB & Background Fuel | | Test 3 (8-22-80) Liquid PCB Fuel Oil | | PCB Mode Operation Test 1 & Test 2 | |
|---|---|---|---|---|---|---|---|---|
| | High | Low | High | Low | High | Low | High | Low |
| $CO_2$ (%) | 8.7 | 8.1 | 9.2 | 7.6 | 7.0 | 7.0 | 9.2 | 7.0 |
| CO (ppm) | 11.5 | 4.0 | 38.0 | 2.0 | 16.0 | 1.0 | 38.0 | 1.0 |
| $O_2$ (%) | 11.5 | 10.5 | 10.9 | 9.8 | 12.1 | 7.9 | 12.1 | 7.9 |
| Hot duct temperature (°F) | 2050 | 2000 | 2264 | 2101 | 2203 | 2106 | 2264 | 2101 |
| Residence time (seconds) | 2.47 | 2.32 | 2.42 | 2.10 | 2.34 | 2.18 | 2.42 | 2.10 |
| Combustion Efficiency | 99.9954 | 99.9863 | 99.9974 | 99.9529 | 99.9986 | 99.9771 | 99.9986 | 99.9529 |

in PCB mode, the hot duct temperature never fell below 2101°F, the maximum CO concentration (as seen by the CO monitor) was 38 ppm, and the shortest residence time was 2.10 seconds. The lowest instantaneous combustion efficiency was calculated to be 99.9529 percent and occurred on the second test day at the same time the CO peaked at 38 ppm.

# 3. FACILITY DESCRIPTION

The facility described in this section is a hazardous waste incinerator operated by Rollins Environmental Services in Deer Park, Texas. This system represents the state of the art for thermal destruction of hazardous wastes. High destruction efficiency and wet scrubbing of the flue gas minimize environmental impacts from plant operation. This description is based on on-site observations, numerous conversations with Rollins personnel, and a previously prepared test report (1). Figure 1 shows a schematic of the incineration process.

## 3.1 INCINERATOR

The incinerator unit at Rollins Environmental Services consists of a rotary kiln for destroying solids, a Loddby burner for firing liquid or gaseous waste, and an afterburner which provides a long residence time for the combustion gases. Although no solids were burned during these tests, the kiln was always fired with background fuel in order to maintain proper temperature distribution throughout the incinerator. No hazardous wastes were fired into the kiln during these tests.

The wastes to be destroyed are fired directly into the Loddby liquid burner via a waste feed line. The waste fuel is held in a mixing tank, where several wastes may be blended in order to achieve good thermal properties for incineration.

Combustion gases from both the Loddby and the kiln enter the afterburner where a long residence time insures maximum destruction of the waste. The afterburner has a rather unusual geometry. Rather than having a simple rectangular shape, it is bent at what is roughly a 45° angle. This provides some turbulence which promotes more thorough mixing of the combustion gases. Similarly, an irregularly shaped hot duct carries gases out of the afterburner. A temperature sensor is located here, as well as probes for

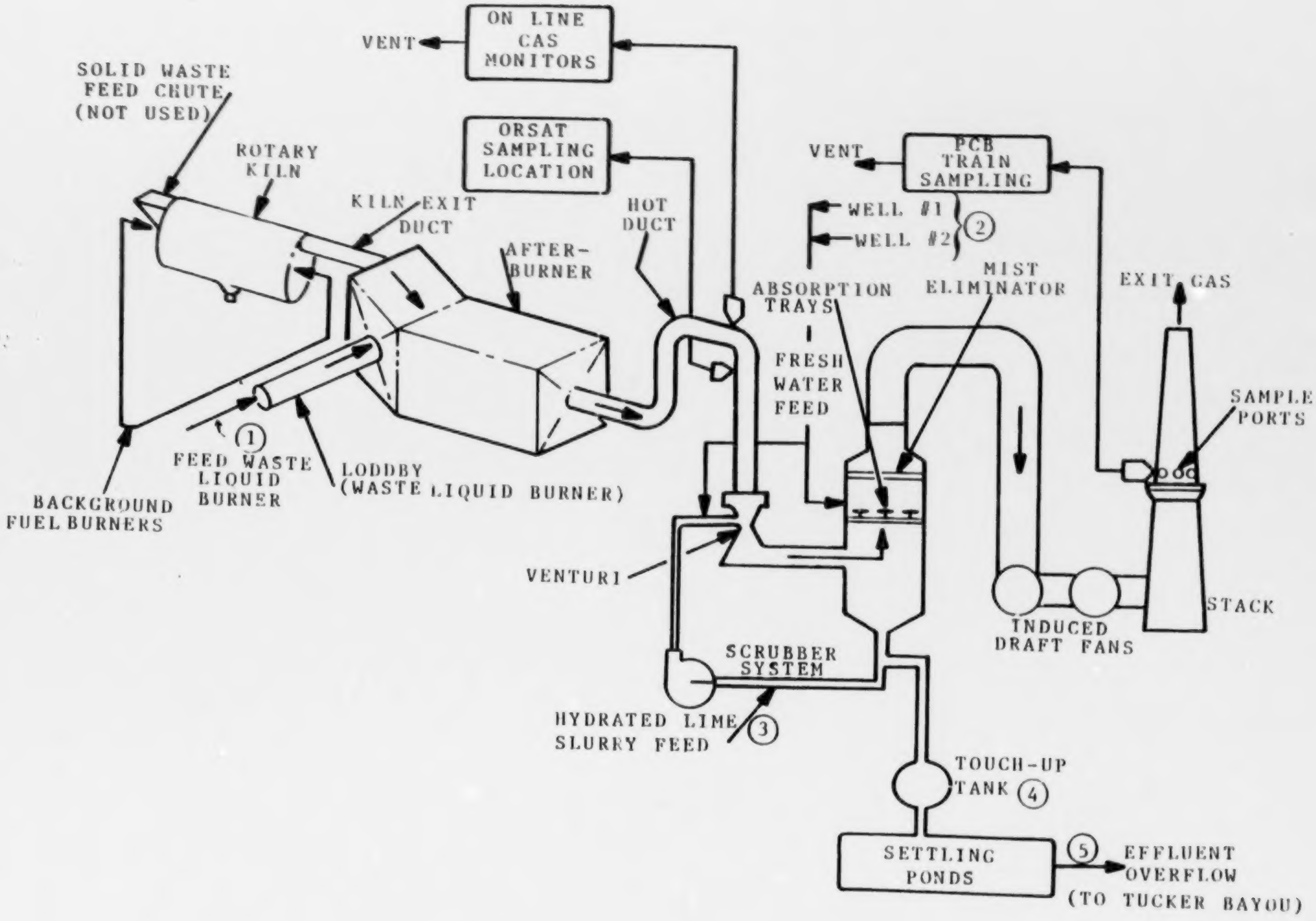


Figure 1. Schematic of Rollins' incineration system.

monitoring CO and $O_2$. These are the measurements used at Rollins to satisfy EPA monitoring requirements for incineration of PCBs. The temperature at this point must never fall below 1100°C (2012°F) while PCBs are being burned or an automatic shutoff system will stop the PCB feed. Similarly, the CO level here must never exceed 80 ppm.

Temperatures in the hot duct are typically maintained above 2100°F, oxygen levels at roughly 10%, and CO levels less than 10ppm while the incinerator is in PCB mode. Temperatures in the kiln and afterburner are usually above 1600°F and 2400°F, respectively. Internal volumes of the thermal destruction units are as follows:

Loddby volume = 491 $ft^3$ = 13.8 $m^3$
Kiln = 1385 $ft^3$ = 38.8 $m^3$ (does not include kiln exit duct)
Afterburner = 6285 $ft^3$ = 176 $m^3$
Hot duct = 1700 $ft^3$ = 47.6 $m^3$

The volumes of the Loddby, afterburner, and hot duct combined provide a total retention time of roughly 2.5 seconds.

## 3.2 SCRUBBER AND DISCHARGE

A wet scrubber system is employed to clean the combustion gases coming out of the hot duct. This system consists of a Venturi scrubber in series with a spray tower scrubber. Hot combustion gas enters the converging section of the Venturi and is impacted by an atomized flow of scrubber liquor just above the throat. This flow varies between 450-500 gallons per minute. Most of the scrubbing action occurs in the throat section. The liquid particles have already begun to coalesce as the gas stream passes through the diverging section of the Venturi. Particulate is removed by impaction with the liquid,and acidic components (particularly HCl) are removed by reaction with the alkaline content of the scrubber liquor.

The combustion gases then pass up through the scrubber tower. Although some scrubbing action does occur here, most of the removal efficiency of the system is due to the Venturi. The purpose of the tower is to separate the liquid phase introduced in the Venturi from the flue gases. A spray of fresh water is introduced at the top of the tower to promote agglomeration of droplets, and gravitational forces cause the liquid to collect on the bottom. In addition, a demister pad is mounted at the top of the tower to prevent the escape of whatever fine droplets may be remaining. Scrubber liquor collecting on the bottom of the tower is divided into two flows, one being drained off for discharge and the other being recycled to the Venturi. Additional hydrated lime slurry is added to the recycle flow in order to maintain the alkalinity of the scrubber liquor, and fresh make-up water is also added to this stream to compensate for the volume discharged and the evaporative losses in the scrubber system.

The combustion gases are cooled substantially by the scrubbing process. The temperature at the scrubber outlet stays very close to 145°F (63°C), which is a drop of roughly 2000°F from typical hot duct temperatures. After scrubbing, the flue gases pass through a pair of induced draft fans in series and finally escape through a 30 meter stack. Together, the induced draft fans provide a maximum of 900 Hp of mechanical work on the flue gas. Their rated capacity is 81,000 $ft^3$/min (38.1 $m^3$/sec) of gas at 170°F and a density of 0.0472 lb/$ft^3$ (0.7561 kg/$m^3$). This provides a total pressure differential of 28 inches water (5.23 cm Hg) over the length of the incinerator system.

Discharged scrubber liquor flows into an open reservoir called the touch-up tank. This is simply an open tank with an agitator to which chemicals can be added in case additional chemical treatment of the waste flow is required. The liquid flows from this tank into a series of four settling lagoons, separated by channels and weirs. The total retention time of this system is from 2 to 4 days, depending on flow conditions. Final discharge is to a local body of water known as Tuckers Bayou.

# 4. SAMPLING AND MONITORING

## 4.1 STACK GAS SAMPLING

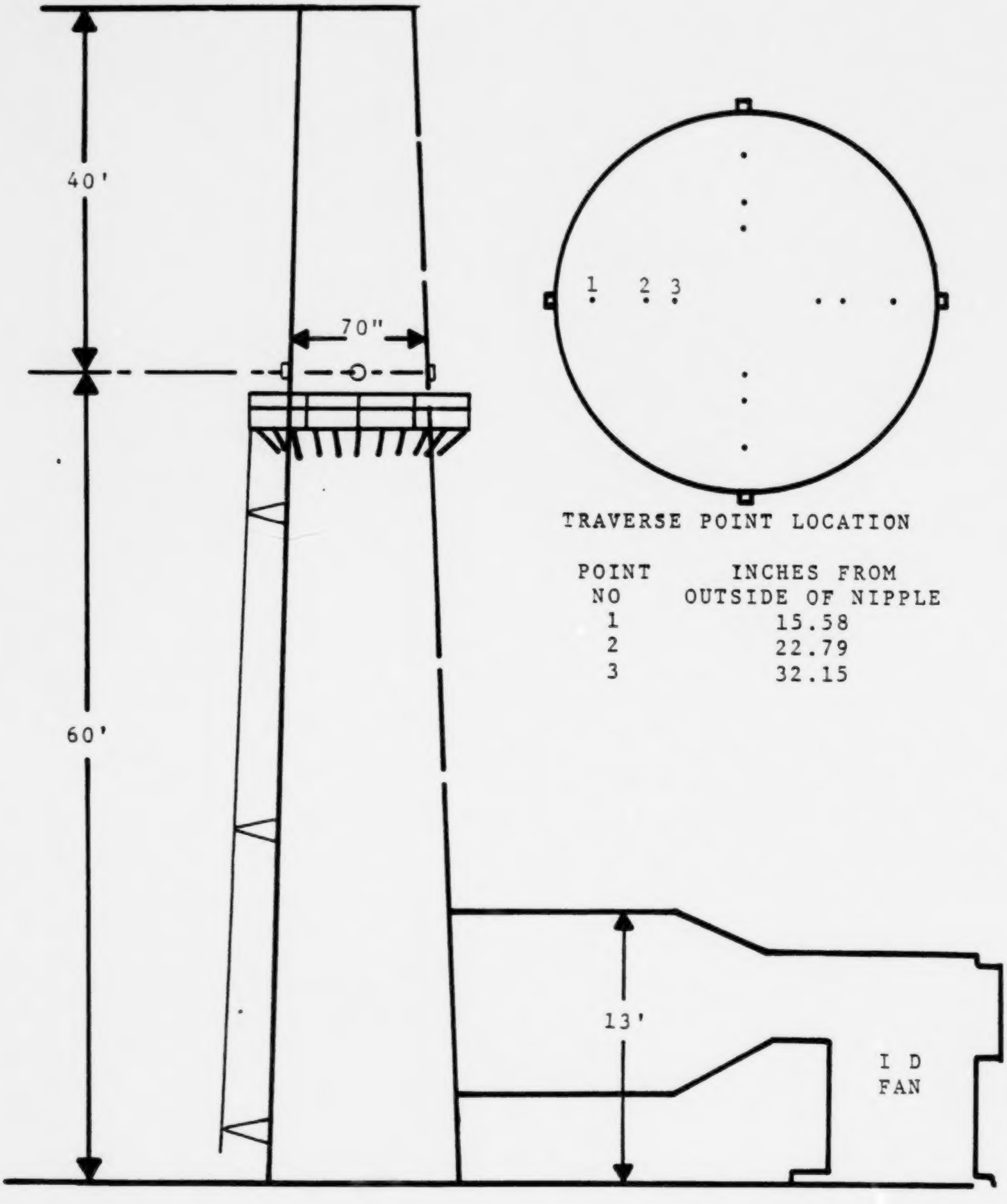
### 4.1.1 Sampling Locations

All sampling locations are identified in Figure 1. Figure 2 is a schematic of the stack including a cross sectional view depicting the traverse point locations.

The inorganic gas samples for molecular weight determination were taken at the stack sampling locations. In addition, an inlet "hot zone" $CO_2$ sample was drawn to determine combustion efficiency. This sample was collected prior to the gas entering the scrubber and undergoing any compositional change.

### 4.1.2 Sampling Train Description

The PCB sampling train, shown schematically in Figure 3, was utilized to collect the organic constituents of the flue gas. The PCB train is a modification of a standard EPA Method 5 train. A solid sorbent trapping system was incorporated downstream of the probe and between the third and fourth impingers. By placing the sorbent traps in this position, the gas stream was relatively dry, as moisture was condensed in the first three impingers. Granular XAD-2 resin was used for the primary sorbent material. As a backup to XAD-2, Florisil was used to adsorb any residual organics or organochlorine compounds that may break through the XAD-2 trap. The two sorbent traps were water-jacketed, and an exiting gas temperature of 16°C (60°F) was maintained by circulating the impinger ice bath water through the jackets (Figure 4). Because of the sensitivity of organics to ultraviolet light, the sorbent traps were wrapped in aluminum foil, and the impingers and interconnecting glassware were also shielded from light.



TRAVERSE POINT LOCATION

| POINT NO | INCHES FROM OUTSIDE OF NIPPLE |
|---|---|
| 1 | 15.58 |
| 2 | 22.79 |
| 3 | 32.15 |

Figure 2. Schematic of stack sampling locations.

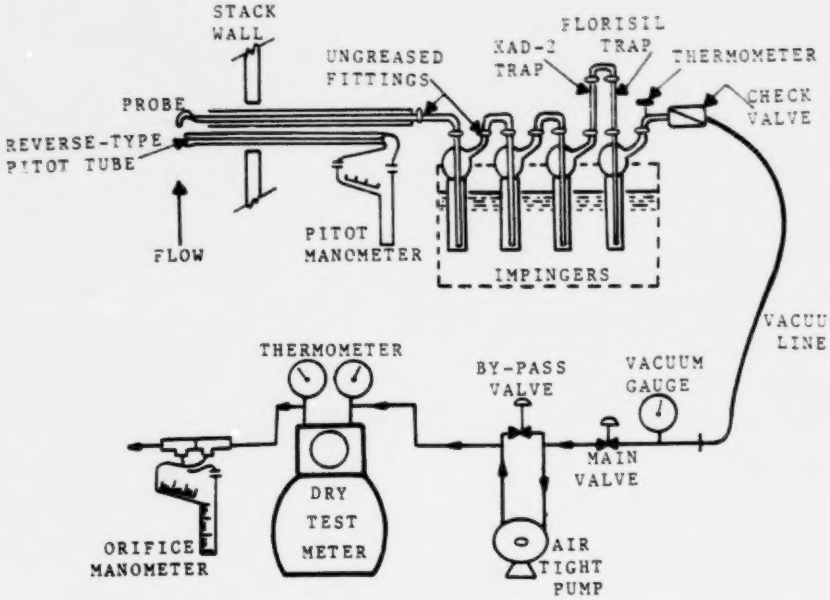


Figure 3. Schematic of PCB sampling train.

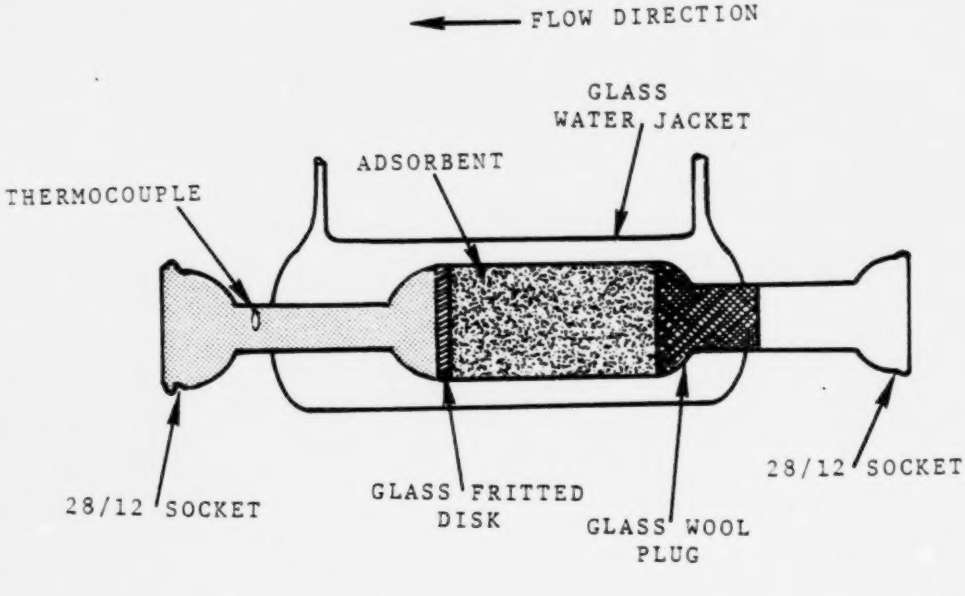


Figure 4. Schematic of adsorbent traps.

### 4.1.3 Operating Procedures

Sampling for organics was performed at the stack outlet location utilizing two PCB trains. Both trains were operated simultaneously at a rate approximating the flue gas velocity (isokinetic sampling in accordance with EPA Method 5, 40 CFR 60). The gas stream was passed through the impinger solutions (water) to condense any moisture present in the stack gas and to collect particulates then through the sorbent system to adsorb the organic constituents. Parameters such as temperatures, pressures, gas volumes were monitored throughout the sampling period.

Prior to test initiation, the sampling trains were leak checked at 15 inches of mercury. If a leak rate greater than 0.02 cfm was observed, the sampling train was systematically checked to find the leak. No train was operated with an unacceptable leak rate. No grease was used on any of the glass fittings. Post-test leak checks were performed at the highest vacuum encountered during the sampling time. Leak checks were also performed prior to each port change or any disassembly of the train.

The sampling time was of 240 minutes duration and at a sampling rate of less than 0.75 cfm.

### 4.1.4 Sample Recovery

Upon completion of testing, each train was removed to a clean area (mobile laboratory) for recovery. Each train was recovered separately to prevent sample mix-up and cross examination. Each train component was recovered per the following:

- Probe and nozzle were wiped to remove residual particulate.
- After recovering dry particulate from the nozzle and probe, these parts were rinsed with acetone and hexane. Rinsate was retained in an amber glass bottle, labeled and sealed.
- Florisil and XAD-2 resin traps were removed from the train, sealed with glass caps, and then wrapped for shipment to the analysis laboratory.
- Impingers - each of the impingers were weighed, weights were recorded, and contents were transferred to amber glass bottles. The impingers were then rinsed with small amounts of acetone and

hexane. Rinses were combined with the impinger catch, and rinse volumes were recorded.

- Silica gel impinger was weighed, recorded, and regenerated for subsequent use.
- After recovery, each sample was labeled (traps) or sealed (bottles) with EPA Chain of Custody tags.

## 4.2 LIQUID/SLURRY SAMPLING LOCATIONS, EQUIPMENT, AND PROCEDURES

This section summarizes the locations in the process where liquid samples were collected and the equipment and procedures used to collect the samples at Rollins Environmental Services, Deer Park, Texas.

### 4.2.1 Location of Sampling Points

Figure 1 illustrates the location of the sampling points in the incineration system. A description of each sampling location is presented below.

- Lime Slurry Feed: Samples of the scrubber lime slurry feed were collected from a valve in the pipeline leading to the scrubber from slurry mixing tank No. 305.
- Well Water: Make-up water for the scrubber and lime slurry originates from three on-site water wells. During the period of testing, August 5-22, 1980, waters from wells No. 1 and No. 2 were being used in a ratio of 2:1, respectively. Both wells were sampled during the testing periods. Samples were collected from a valve in the well water pipelines leading to the scrubber.
- Touch-up-Tank: The touch-up-tank (TUT) is an open fiberglass tank, fitted with a mechanical agitator and located adjacent to the base of the stack. Samples were removed directly from the tank.
- F-4 Discharge: Samples of the F-4 discharge were collected from the flow through the fiberglass weir separating the No. 4 settling lagoon and the receiving stream. This was located ~100 yards south of the stack and averaged 7 inches of discharge water depth flowing across the weir during each test period.
- Liquid PCBs - Chlorinated Organic Waste - Fuel Oil: Fuel oil and liquid wastes or PCBs were premixed prior to the tests. Samples were collected from a valve in the pipeline just prior to introduction to the Loddby burner.

### 4.2.2 Sampling Equipment and Procedures

This subsection describes the equipment and procedures used to collect the various types of samples during the test periods.

- Process Stream Sampling Equipment: All liquid process stream (lime slurry feed, well water, touch-up-tank, F-4 discharge, liquid waste feeds) samples were collected in duplicate clean, amber glass jars (250 ml) with Teflon seals in the caps. The duplicate individual 250 ml samples were transferred to two clean amber glass bottles (2000 ml) to obtain duplicate composite samples for each stream. Each sample container and compositing jug was labeled prior to sample collection.

- Process Stream Sampling Procedures: All liquid process streams (liquid waste feeds, well water, lime slurry, touch-up-tank, F-4 discharge) were sampled in the same manner. Duplicate 250 ml samples of each liquid stream were collected and immediately transferred to 2000 ml compositing jugs. Each liquid stream had its own sampling jar and compositing jugs which were sealed with Teflon lined caps when not in use. Each liquid stream was sampled every 30 minutes during each test. At the conclusion of a test, the compositing jugs were sealed, tagged, and readied for shipment to Wright State University.

  At the request of R.E.S. and the EPA, sample collection jars, valves, and lines were not flushed with liquid so as to avoid generating large volumes of waste which would have required extra handling as hazardous wastes. In addition, for well water collection, the sample collection jar was marked at the proper liquid volume levels, 166.7 ml and 83.3 ml, to provide proportional sample collection volumes of the two well water sources, well number 1 and well number 2, respectively.

### 4.3 PROCESS MONITORING

While the three tests were being performed, records were kept of operating parameters within the incinerator plant. These included temperatures, combustion gas concentrations, waste feed rates, and scrubber operations as described in subsequent subsections. Calculations for residence time and combustion efficiency are also presented.

The information presented here has been reduced from the raw data sheets included in Appendix C. Means and standard deviations have been calculated for each test day whenever possible. In most cases the data were recorded at 15 minute intervals. Any exceptions have been noted.

### 4.3.1 Temperature

Three temperatures characterizing the incineration process were measured. These include the hot duct, afterburner, and kiln temperatures, all of which were indicated in degrees Fahrenheit by digital readouts in the plant's control room. In addition, paper copies were made by strip chart recorders. There was no facility for measuring the Loddby temperature. All furnace temperatures were measured by thermocouples in contact with the gas stream. No temperature instrumentation problems were encountered during any of the tests.

Table 7 provides a summary of all relevant temperature data, including mean, standard deviation, minimum value, and maximum value for each of the three test days. Values are expressed in both degrees Fahrenheit and degrees Celsius, although the actual calculations were carried out in degrees Fahrenheit (i.e., only the standard deviation corresponding to °F is given). The overall mean temperatures (all three test days) for the kiln, hot duct, and afterburner were 1440°F (782°C), 2108°F (1153°C), and 2403°F (1317°C), respectively. The lowest temperatures were found in the kiln, which is acceptable since no PCBs were being fired there. The highest temperatures are found in the combustion chamber, as expected. The maximum combustion chamber temperature ranged between 2000-2050°F (1093-1121°C) during the background test and 2101-2264°F (1149-1240°C) for the PCB tests. It is required by EPA (40 CFR 761.40) that the minimum afterburner temperature be 2012°F (1100°C). The hot duct temperature is considered representative of this value.

### 4.3.2 Residence Time

Residence times were calculated by dividing the stated volume of the combustion region by the volumetric flow rate of the combustion gases corrected for temperature (2). Correction for pressure was not made because the pressure in the system was negligibly different from atmospheric. Mathematically,

$$\text{Residence time} = RT = \frac{V}{Q} = \frac{V}{m/\rho}$$

Where V = volume of the combustion zone ($ft^3$), Q = volumetric flow rate ($ft^3$/sec), m = mass flow rate (lb/sec), and $\rho$ = density ($lb/ft^3$) of the combustion gas, respectively.

## TABLE 7. SUMMARY OF TEMPERATURE DATA

| Temperature Sensor Location | Temperature (°F or °C, as Indicated) |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | Background Fuel (Test #1, 8-6-80) |  |  |  | PCB & Background Fuel (Test #2, 8-7-80) |  |  |  | PCB & Fuel Oil (Test #3, 8-22-80) |  |  |  |
|  | $\bar{x}$* | s | MAX | MIN | x | s | MAX | MIN | x | s | MAX | MIN |
| Kiln | 1542°F | 20.99 | 1577°F | 1468°F | 1176°F | 267.54 | 1668°F | 622°F | 1602°F | 59.48 | 1736°F | 1504°F |
| — | 839°C | - | 858°C | 798°C | 636°C | - | 909°C | 328°C | 872°C | - | 947°C | 818°C |
| Hot Duct | 2028°F | 12.17 | 2050°F | 2000°F | 2145°F | 29.40 | 2264°F | 2101°F | 2152°F | 26.70 | 2203°F | 2106°F |
|  | 1109°C | - | 1121°C | 1090°C | 1174°C | - | 1240°C | 1199°C | 1178°C | - | 1206°C | 1152°C |
| After-burner | 2289°F | 44.04 | 2500°F | 2228°F | 2455°F | 130.79 | 2696°F | 2253°F | 2464°F | 58.14 | 2640°F | 2370°F |
|  | 1254°C | - | 1371°C | 1200°C | 1346°C | - | 1480°C | 1234°C | 1351°C | - | 1449°C | 1299°C |

*Means were calculated using values of °F:
Hence, standard deviations are not given for means of °C

Gas density as a function of temperature can be calculated from the following relationship (2):

$$\rho = \frac{Tref}{(13.1)\ Tcomb}$$

Where $\rho$ = density in lb/ft$^3$, Tref = 60°F (520°R), the constant 13.1 is the volume (ft$^3$) occupied by 1 lb of air at 60°F and 1 atmosphere pressure, and Tcomb is the combustion zone temperature.

The above two expressions can be combined into the following relationship:

$$RT = \frac{(V, ft^3)(540, {}^\circ R)}{(13.1,\ ft^3/lb)(m,\ lb/sec)(Tcomb,\ {}^\circ R)}$$

During these tests, PCB wastes were fired through the Loddby burner. Thus, the total combustion volume is the sum of the volumes of the Loddby burner (49/ft$^3$), the afterburner (6285 ft$^3$), and the hot duct up to the point of temperature measurement (1700 ft$^3$). The total volume is 8476 ft$^3$ or 237.4 m$^3$.

The mass flow rate of combustion gas can be determined from the induced draft fan curves and a knowledge of how much water is added to this flow by the scrubber. The fans are capable of drawing 81,000 ft$^3$/min at a gas density of 0.0472 lb/ft$^3$, which corresponds to a mass flow rate through the fans of 63.72 lbs/sec. However, this flow contains water evaporated from the scrubber which was not contained in the original combustion gas flow. The scrubber approximates an adiabatic saturation process. Therefore, by knowing that the scrubber outlet temperature is close to 150°F (65.6°C) and assuming atmospheric pressure through the fans (a conservative assumption), the water content of the gas can be found by using thermodynamic principles (3). The flow of dry combustion gas under these conditions is 52.71 lbs/sec (23.91 kg/sec).

At Rollins, the temperature in the hot duct was maintained above the regulatory minimum of 1200°C ± 100°C (at 3% excess oxygen). Thus, the hot duct temperature is taken as Tcomb. Hot duct temperatures are given in Tables 5 and 6.

Tables 5 and 6 summarize residence times which ranged from 2.10 seconds to 2.42 seconds and which were above the regulatory minimum of 2 seconds (at 1200°C ± 100°C and 3% excess oxygen).

### 4.3.3 Combustion Gases and Combustion Efficiency

Three parameters are considered important in order to characterize the combustion gas composition. These are the measurement of concentrations of carbon monoxide (CO), carbon dioxide ($CO_2$), and oxygen ($O_2$). Combustion efficiency is related to levels of CO and $CO_2$ in the gas stream leaving the afterburner. The presence of significant levels of $O_2$ in the gas stream insures that enough oxygen was present in the combustion chamber for complete oxidation of the waste. A tabulation of combustion gas data for the three test days is given in Table 8.

Carbon monoxide was measured with a nondispersive, infrared type (EPA Reference Method 10) continuous monitor (Beckman Model 865). A sample line provided gas from the breach of the stack to the instrument located in the instrument room. The CO monitor also provided a signal for a strip chart recorder, which was located in the control room.

Considerable difficulty was experienced with the CO monitor during these tests. Upward drift was very noticeable during the first and second test days; and, although improved, was still present on the third day. In fact, nearly an entire day of CO data was lost during the first test while repairs were attempted. The monitor was recalibrated twice during each PCB burn, but this was not enough to avoid artifically high daily mean CO concentrations. These means were 20.1 ppm and 6.1 ppm for tests two and three, respectively. The daily mean for the first test day has been calculated to be 9.3 ppm, but this is for only 9 observations, as opposed to 34 observations for test two and 32 observations for test three. Every time the monitor was recalibrated its output was below 3 ppm, suggesting that even the 6.1 ppm value is too high.

Regardless of the CO monitor drift problem, the CO monitor never recorded a concentration higher than 38 ppm; the maximum allowed by EPA for this incinerator was 80 ppm. This concentration was calculated from the combustion efficiency (99.9%) and $CO_2$ concentration (8%). Plant operation was permissible

TABLE 8. SUMMARY OF COMBUSTION GAS CONCENTRATIONS AND COMBUSTION EFFICIENCIES

| | Test One (8-6-80) Background Fuel | | | | | Test Two (8-7-80) PCB & Background Fuel | | | | | (Test Three (8-22-80) PCB & Fuel Oil | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | $\bar{x}$* | s* | n* | Max | Min | $\bar{x}$ | s | n | Max | Min | $\bar{x}$ | s | n | Max | Min |
| CO (ppm) Continuous monitor) | 9.3 | 2.50 | 9 | 11.5 | 4.0 | 20.1 | 11.95 | 34 | 38.0 | 2.0 | 6.1 | 4.93 | 31 | 16.0 | 1.0 |
| $CO_2$ (%) (ORSAT analysis) | 8.4 | 0.16 | 8 | 8.7 | 8.1 | 8.2 | 0.41 | 12 | 9.2 | 7.6 | 7.0 | - | 1 | 7.0 | 7.0 |
| $O_2$ (%) (ORSAT analysis) | 11.0 | 0.32 | 8 | 11.5 | 10.5 | 10.5 | 0.43 | 11 | 10.9 | 9.8 | - | - | - | - | - |
| $O_2$ (%) (Continuous monitor) | 13.0 | 1.89 | 28 | 11.2 | 9.4 | - | - | - | - | - | 9.6 | 2.53 | 32 | 12.1 | 7.9 |
| Combustion Efficiency (%) | 99.9883 | 0.0023 | 9 | 99.9919 | 99.9862 | 99.9753 | 0.0137 | 34 | 99.9975 | 99.9529 | 99.9893 | 0.0071 | 32 | 99.9957 | 99.9801 |

$\bar{x}$, s, and n are, respectively, mean, standard deviation, and number of data points.

while the CO monitor was down since no PCBs were burned on the first test day.

All carbon dioxide measurements were determined by gas chromatographic (GC) analysis. The procedures involved and a tabulation of results are given in Appendix A. Because of the time involved with collecting a sample for analysis, 15 minute sampling intervals were not possible. The $CO_2$ data in Table 8 were all taken from the scrubber inlet location, i.e., the sampling was performed in the hot duct. This is the appropriate location for combustion gas evaluation. It can be seen in Table 8 that the $CO_2$ values ranged between 7.0 and 8.4%. The first two test days gave fairly similar results, and the low standard deviations shown that a high level of replication (i.e., stable combustion) was achieved. The $CO_2$ value for the third test day is somewhat lower, possibly because fuel oil was being fired instead of chlorinated hydrocarbons. It must be pointed out that only one good sample was analyzed on this day, because leakage through an open port in the hot duct caused subsequent values to be much lower. However, this is still the lowest $CO_2$ value throughout the three tests. The next lowest was 7.6%, encountered during test two. The maximum value, 9.18%, was also encountered during the second test day.

Combustion efficiency, as a function of $CO_2$ and CO concentrations, can be calculated as follows (2):

$$\text{Combustion efficiency} = \text{CE} = 100 \text{ X } \frac{\%\ CO_2}{\%\ CO_2 + \%\ CO}$$

where the levels of $CO_2$ and CO are both given as percent concentrations. The results of this calculation for the three test days are given in Table 8. Since low CO levels result in high combustion efficiencies, it is not surprising to see the highest combustion efficiency occurring on the day on which drift of the CO monitor was least evident. This was the third test day, and a mean combustion efficiency of 99.9893% was calculated. The day on which CO monitor drift was most evident gave the lowest mean combustion efficiency, i.e., 99.9753% on the second test day. However, even the lowest instantaneous combustion efficiency of 99.9529% (encountered on the second test day) is still above the minimum acceptable value, set at 99.9% by the EPA. This value, in fact, corresponds to a CO concentration of 80 ppm, which is the upper limit for CO (assuming an 8% concentration of $CO_2$). Thus, the incinerator would have been well within operating guidelines even if these had been true readings for CO.

Oxygen was measured using a Thermox WDG continuous monitor. A sample line provided gas from the hot duct, and signals were recorded on a strip chart as for CO monitoring. Some difficulty was experienced with this equipment also, because of plugging of the $O_2$ probe with particulate matter. Thorough cleaning of the probe provided good continuous monitoring data for the third test day, but the GC analyses were considered more accurate for the first two days. Daily means and standard deviations of oxygen data are given in Table 8. Low standard deviations for the GC analyses again show a high level of replication and, hence, stable combustion. The lowest instantaneous value of $O_2$ recorded was 7.9%. This is well above the 3% minimum required by EPA regulations (40 CFR 761.40). In general, $O_2$ levels remained fairly constant throughout the tests. The daily means were 11.0% (GC), 10.5% (GC), and 9.6% (continuous monitor) for the first, second, and third test days, respectively.

### 4.3.4 Waste Feed Data

The only waste feed monitored was the flow of PCB waste through the Loddby liquid burner. On the first test day, no PCBs were fired, and no feed rate data were collected because there was no flow through the Loddby. Background fuel was being fired into the combustion chamber on this day, and a characterization of this fuel was obtained from the chemistry lab at Rollins. These data appear in Table 9 with characterizations of the PCB mixtures burned on the two subsequent test days. The PCB content of these mixtures is unknown pending an outside laboratory analysis.

The waste flow monitored during the last two test days was the only source of PCBs into the incinerator. There were a number of ways to measure this flow rate, including an instantaneous readout in the plant's control room, a readout of waste volume in the storage tank, and a flowmeter attached to the feed pipe itself. However, the instantaneous flow readout was not properly calibrated on the second test day (the first PCB test), and data from the mechanical flowmeter were not taken until the third test day. Therefore,

## TABLE 9. FUEL CHARACTERIZATION DATA (BASED ON ROLLINS LABORATORY DATA)

| Fuel Property | Background Fuel (Fired Into Combustion Chamber During Test One & Test Two) | PCB Mixture #1 (Fired Through Loddby During Test Number Two) | PCB Mixture #2 (Fired Through Loddby During Test Number Three) |
|---|---|---|---|
| Specific Gravity | 1.10 | 1.20 | 1.10 |
| ΔH, (BTU/lb) | 9,800 | 14,400 | 12,070 |
| Cl (Weight %) | 35% | 19.3% | 28.2% |
| Ash (Weight %) | 1.71% | 0.57% | 0.65% |
| Scrubbing Efficiency (lbs lime/lbs fuel) | - | 0.090 | 0.185 |

the volume of waste burned was chosen as the most consistent (and probably the most accurate) basis for calculating average waste flow rate.

Waste volume level in a given storage tank (T-27 in this case) was measured by a sensor at the bottom of the tank. This sensor measured the weight of the column of liquid resting on top of it. A digital readout in the control room indicated this value but was calibrated to indicate the total volume of waste in gallons, assuming a specific gravity of one (i.e., the readout indicates what the volume of the liquid would be if the tank were full of water). Therefore, this readout must be divided by the specific gravity of the waste to find the true volume of liquid in gallons. A digital readout was also provided to measure density in the tank, but the laboratory values (Table 9) would be more accurate. The average PCB mixture flow rate can then be calculated by taking the difference of tank volumes at the beginning and end of each test and dividing by the test duration time. The following results were obtained, where $\dot{Q}$ is the waste feed rate:

$$\dot{Q}_{\text{test two, volume method}} = 7.48 \text{ gal/min}$$

$$\dot{Q}_{\text{test three, volume method}} = 9.51 \text{ gal/min}$$

The other two methods were considered fairly accurate for test three and are included here for comparative purposes. Note that the instantaneous flow readout was calibrated to read twice the actual flow and that this was the way the raw data were recorded. The mechanical flow meter data were recorded directly in terms of actual flow.

$$\dot{Q}_{\text{test three, instantaneous flowmeter}} = 9.2 \text{ gal/min}$$

(n = 32, standard deviation = 0.04)

$$\dot{Q}_{\text{test three, mechanical flowmeter}} = 9.2 \text{ gal/min}$$

(n = 26, standard deviation = 0.56)

### 4.3.5 Scrubber Operation and Liquid Discharge

Hourly readings of most important scrubber paramters were taken by Rollins personnel. Means and standard deviations for these over the test periods are given in Table 10, including scrubber temperature, pressure drop across the Venturi, Venturi liquid flowrate, touch-up tank pH, and final discharge pH. Parameters of interest that were unavailable include total fresh water feed to the scrubber system, scrubber recycle flow, lime input, and discharge flow through the touch-up tank.

The scrubber temperatures can be seen to be around 150°F (65.6°C). The exiting flue gas is probably a little cooler than this. The pressure drop across the Venturi throat relates directly to the scrubber efficiency achieved. Larger pressure drops will give higher efficiencies, and all of the means were close to 40 inches $H_2O$ (7.5 cm Hg) which is the normal operating range for this scrubber. The Venturi liquid flowrate, which includes recycle and fresh-water flows into the Venturi throats remained close to 500 GPM (0.032 $m^3$/sec).

The flow through the touch-up tank was, on the whole, slightly acidic. Large standard deviations indicate that large pH swings occurred, and these oscillations could in fact be seen on a strip chart recorder. Apparently, lime is added to the scrubber at intervals, rather than on a continuous basis. The long retention time of the four ponds dampens out these variations, however, and the final discharge is always slightly alkaline.

## 4.4 QUALITY ASSURANCE

### 4.4.1 Test Preparation

All steps needed to clean the train, as well as all glass sample containers, are listed in Figure 5. All impingers used for organic collection were fired to 450°F, nitric acid washed, distilled water rinsed, acetone rinsed, and hexane rinsed. Prior to initial assembly of the train in the field, all parts were rinsed with hexane. This solvent was discarded. All subsequent field cleanings were with glass-distilled water, acetone, and hexane. Only Burdick and Jackson "Distilled-in-Glass," or equivalent, organic solvents were used. Visual inspection for contamination was also performed.

## TABLE 10. SUMMARY OF SCRUBBER AND DISCHARGE DATA*

| Parameter | Test One (8-6-80)<br>Background Fuel | | Test Two (8-7-80)<br>PCB & Background Fuel | | Test Three (8-22-80)<br>PCB & Fuel Oil | |
|---|---|---|---|---|---|---|
| | $\bar{x}$ + | s + | $\bar{x}$ | s | $\bar{x}$ | s |
| Scrubber temperature | | | | | | |
| Venturi liquid flowrate | | | | | | |
| Venturi Δp | | | | | | |
| Touch-up tank pH | | | | | | |
| Outfall pH | | | | | | |

---

* Rollins Environmental Services, Deer Park, Texas, considers the data in Table 10 to be confidential business information as provided for by the Toxic Substances Control Act (TSCA). A copy of these data is on file with the Document Control Officer at the U.S. Environmental Protection Agency's Region 6 Office. To obtain these data, application must be made under the appropriate provisions of TSCA.

+ $\bar{x}$ and s are, respectively, the mean and standard deviation.

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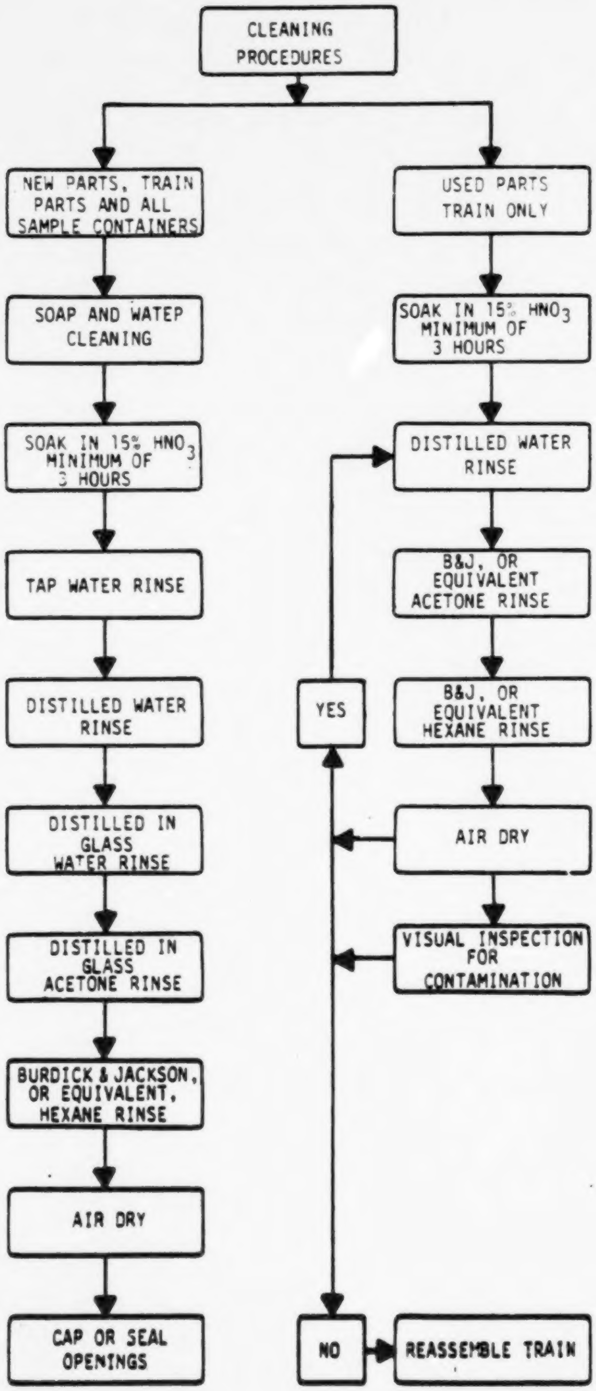
CLEANING PROCEDURES
NEW PARTS, TRAIN PARTS AND ALL SAMPLE CONTAINERS
USED PARTS TRAIN ONLY
SOAP AND WATEP CLEANING
SOAK IN 15% $HNO_3$ MINIMUM OF 3 HOURS
SOAK IN 15% $HNO_3$ MINIMUM OF 3 HOURS
DISTILLED WATER RINSE
TAP WATER RINSE
B&J, OR EQUIVALENT ACETONE RINSE
DISTILLED WATER RINSE
YES
B&J, OR EQUIVALENT HEXANE RINSE
DISTILLED IN GLASS WATER RINSE
AIR DRY
DISTILLED IN GLASS ACETONE RINSE
VISUAL INSPECTION FOR CONTAMINATION
BURDICK & JACKSON, OR EQUIVALENT, HEXANE RINSE
AIR DRY
CAP OR SEAL OPENINGS
NO
REASSEMBLE TRAIN

Figure 5. Schematic of train cleaning operations.

To avoid contaminating the trains as they were assembled or disassembled, as much work as possible was done inside the designated lab area in the mobile van. PCB samples were never brought into the van.

SMOKING was prohibited in all but designated areas. Prohibited areas included the stack and other sampling locations. Exposure of resin traps was kept to a minimum. If any equipment was contaminated, it was completely recleaned. All organic solvents were stored in amber glass containers. No grease of any type was used on the train including the impingers. If a seal could not be attained, that part was replaced.

The adsorbents used through the PCB test sequences were cleaned by the following methodology.

- 10 gallons of distilled water was rinsed through the XAD-2 resin to remove residual salts
- A 24 hour continuously reflux of "Distilled-In-Glass" methanol
- For XAD-2, a 24 hour reflux with "Distilled-In-Glass" methylene chloride
- For Florisil, a 24 hour reflux of a blend of 5% diethyl ether and 95% hexane to remove organics
- Both adsorbents were then dried under constant flowing nitrogen until no residual organic odor was detected
- After drying, Florisil was heated for 2 hours at 650°C and allowed to cool
- XAD-2 and Florisil traps were packed and sealed in the laboratory

### 4.4.2 Method Five Calibration Data

#### 4.4.2.1 Orifice Meter Calibration--

The orifice meter calibration is performed using a pump and metering system as illustrated in Figure 6 (a). The dry gas meter with attached critical orifice is run at various orifice flows for a known time. After each run the volume of the dry gas meter, meter inlet/outlet temperatures, time, and orifice setting is recorded. The orifice meter calibration factor is derived by solving the equation:

$$\Delta H@ = \frac{0.317 \ \Delta H}{Pb\ (T_d + 460)} \left[ \frac{(Tw + 460)\ \theta}{Vw} \right]^2$$

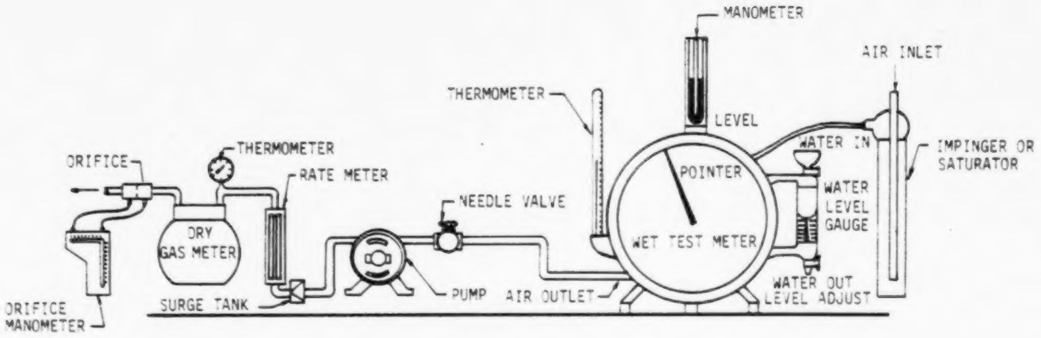

Figure 6a. Orifice and dry gas meter calibration.

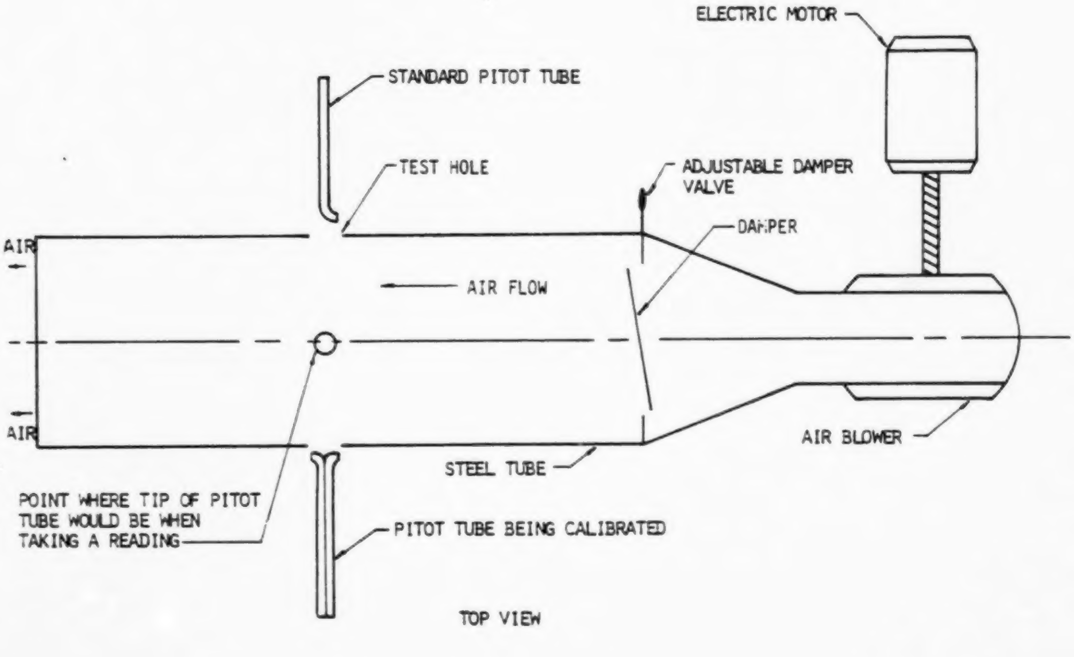

Figure 6b. Pitot tube calibration.

where

$\Delta H$ = Average pressure drop across the orifice meter, inches $H_2O$

Pb = Barometric pressure, inches Mercury

$T_d$ = Temperature of the dry gas meter, °F

Tw = Temperature of the wet test meter, °F

$\Theta$ = Time, minutes

Vw = Volume of wet test meter, cubic feet

The $\Delta H@$ yielded is utilized to adjust the sampling train flow rate by regulating the orifice flow.

4.4.2.2 Dry Gas Meter Calibration--

Meter box calibration consists of checking the dry gas meter for accuracy. The dry gas meter with attached critical orifice is connected to a wet test meter, Figure 6 (a), and run at various orifice flows for a known time. After each run wet and dry gas meter volumes, temperatures, time, and orifice readings are recorded. Utilizing the equation:

$$V = \frac{Vw\ Pb\ (Td + 460)}{Vd\ (Pb + \frac{\Delta H}{13.6})\ (T_w + 460)}$$

where

V = Volume correction factor (also known as "Y" in EPA Method 5)

Vw = Volume of wet test meter, cubic feet

Pb = Barometric pressure, inches mercury

Td = Temperature of dry gas meter, °F

Vd = Volume of dry gas meter, cubic feet

$\Delta H$ = Average pressure drop across the orifice meter, inches $H_2O$

$T_w$ = Temperature of wet test meter, °F

A volume factor which compares the dry gas meter with the wet test meter is obtained.

4.4.2.3 Pitot Tube Calibration--

Pitot tubes are calibrated on a routine basis utilizing two methods. The type S pitot tube specifications are illustrated and outlined in the Federal Register, Standards of Performance for New Stationary Sources, [40 CFR Part 60], Reference Method 2 (refer to Figure 6 (b)). When measurement of pitot openings and alignment verify proper configuration, a coefficient value of 0.84 is assigned to the pitot tube.

If the measurements do not meet the requirements as outlined in the Federal Register, a calibration is then performed by comparing the S type pitot tube with a standard pitot tube (known coefficient of 1.0). Under identical conditions, values of P, for both S-type and standard pitot tubes are recorded using various velocity flows (14 fps to 60 fps). The pitot tube calibration coefficient is determined utilizing the following equation;

$$\begin{array}{l}\text{Pitot Tube Calibration}\\ \text{Factor (CP)}\end{array} = \begin{array}{l}\text{(Standard Pitot Tube}\\ \text{Coefficient)}\end{array} \times \left[ \frac{\text{P reading of std. pitot}}{\text{P reading of S type pitot}} \right]^{1/2}$$

The coefficient assigned to the pitot tube is the average of calculated values over the various velocity ranges.

4.4.2.4 Nozzle Diameters--

The nozzle diameters were calibrated with a vernier caliper. If the nozzle showed excessive wear or was considered not fit for use, it was discarded.

4.4.3 Instrument Calibration

Manufacturer's recommended calibration procedures were followed using the following standard gas mix which had an accuracy of ± 2%:

| | |
|---|---|
| Carbon dioxide | 15% |
| Oxygen | 5.15% |
| Carbon monoxide | 7.23% |
| Nitrogen | Balance |

Calibrations were performed prior to the start of each test day. Replicate injections of the standard gas mixture were made until a comparison of corresponding peak heights was in agreement to within 5%. At this point, the gas chromatograph was considered calibrated and ready for sample analysis. A strip chart recorder was used to record both the calibration and test data.

### 4.4.4 Blanks

For each test conducted at the Rollins facility, a blank sampling train was set up. The blank train consisted of the back half of the PCB train, i.e., impingers, impinger solutions and resin traps. Prior to the start of a specific test, the blank train was transported to the stack where it remained, protected from light, for the duration of the test. Upon completion of the test, the blank was recovered utilizing the same recovery procedures as the test sample.

In addition to the blank train, a small portion of the solvents, approximating the amount used in rinsing the train, was composited during each test cleanup and submitted as a solvent blank.

### 4.4.5 Chain of Custody

Once the samples were recovered from the sampling trains and liquid streams, they were labeled, taped, and shipped according to EPA's chain of custody requirements.

The samples were individually wrapped with bubble-pak or other suitable packaging material, placed in shipping containers, and then given to Federal Express Airborne or United Parcel Service for shipment to Wright State Universith Laboratory. A chain of custody form accompanied each sample shipment and each sample/shipment was sealed and labeled with EPA chain of custody tags. See Appendix E for the daily chain of custody record forms.

## 5. TECHNICAL PROBLEMS AND RECOMMENDATIONS

The major problem that occurred during the tests at Rollins was plugging of the sorbent traps. This problem caused delays and loss of one test day. A brown to red-brown material was distributed throughout the train but appeared to be concentrated particularly in the glass frit of the XAD-2 sorbent trap. This material could be either organic or inorganic in nature. It should be noted, however, that the material passed through two water filled, ice bath cooled impingers before entering the XAD-2 trap.

It was recommended that the material be analyzed, so that this problem might be avoided in future test projects. These analyses are underway at Wright State University.

There were minor problems: wrong length probes, occasional leaks in the trains, and some samples broken in shipment. These problems would have been lessened had the test preparation period been longer than two weeks and had a wider selection of shipping companies been available. Also solid shipping containers such as metal ice chests should be used instead of cardboard shipping cartons.

There were minor facility problems, especially with the CO monitor as noted in Chapter 4. Once again, a longer lead time for test preparation might have reduced these problems.

# REFERENCES

1. Rollins Environmental Services. The PCB Incineration Test Made by Rollins Environmental Services (TX) at Deer Park, Texas, November 12-16, 1979. Report prepared for U. S. EPA, Region VI.

2. Beard, J. H, and J. Schaum. Sampling Methods & Analytical Procedures Manual for PCB Disposal: Interim Report. Report prepared by U. S. EPA, Office of Solid Waste, February 10, 1978.

3. Van Wylen, G. J., and R. E. Sonntag. Fundamentals of Classical Thermodynamics. John Wiley & Sons, New York, 1976.

# APPENDIX A
## GASEOUS MONITORING

Monitoring of oxygen and carbon dioxide for stack gas molecular weight determination was performed at the Rollins facility. The sampling positions were located at ports midway on the stack exit after the incineration and scrubber units. However, at the Rollins facility, the $CO_2$ concentration undergoes changes as the gas passes through the caustic scrubber system. For this reason and to determine combustion efficiency, samples of stack gas were extracted at the "hot" duct leading from the burner unit to the scrubber.

The gas sample was drawn through a stainless steel probe, polypropylene tubing, and an ice bath condenser by means of a small diaphragm pump. A flow rate meter was used to measure sample flow to a Tedlar bag. The collected gas sample was then analyzed for carbon dioxide, oxygen, and nitrogen with a thermal conductivity detector gas chromatograph. The collection device consisted of the following components.

- Probe - stainless steel with a glass wool plug to act as a filter
- Condenser - air cooled or ice bath to eliminate excess moisture
- Valve - needle valve to regulate sample gas flow rate
- Pump - leak-free, diaphragm type, or equivalent to transport sample gas to the Tedlar bag
- Flow rate meter - meter capable of measuring a flow range from 0 to 1.0 liter per minute
- Gas sample bag - Tedlar sample bag or equivalent, with a capacity of approximately 0.5 - 1.0 cubic foot
- Manometer - water filled U-tube or dry gas meter to be used for the Tedlar bag leak check
- Vacuum gauge - gauge or meter to be used for the sample train leak check.

Prior to field use, all Tedlar gas sample bags were leak checked. The bags were leak checked by inflating them to a pressure of 5 to 10 cm $H_2O$ (2-4 in Hg) as determined by an in-line manometer or equivalent. Any displacement in the manometer after a 10-minute time interval was taken as indicative of a leak. In the field prior to the sampling operation, the sampling train was also leak checked. The leak check was done by placing a vacuum gauge at the probe inlet, pulling a vacuum of at least 250 mm Hg (10 in. Hg), and then turning off the pump. The vacuum should remain stable for at least one minute.

A sample was taken as follows:

- Place the probe in the stack at the sampling point and purge the sample line up to the bag.
- Connect the bag and make certain that all connections are tight.
- Fill and evacuate bag twice before taking analysis sample.
- Sample at a rate that will fill the bag in 10 minutes.
- Remove full bag, cap opening, transport to lab, and analyze as soon as possible.

In the lab area, the Tedlar bag was analyzed on the Shimadzu gas chromatograph, model GC-3BT. The resultant peak heights were compared to a known standard gas purchased from Scott Environmental Technology, Inc.

Table A-1 presents the gas analysis data as collected from both the "hot zone" and outlet sampling points at the Rollins Facility.

TABLE A1. GAS MONITORING DATA

| Date (1980) | Time Sampled (hrs) | Sampling Location | Results<br>$CO_2$ % | <br>$O_2$ % | Comments |
|---|---|---|---|---|---|
| 8/5 | 1338-1358 | Hot zone | 7.33 | 10.45 | |
| | 1703-1720 | " | 8.35 | 9.49 | |
| | 1915-1935 | " | 8.80 | 9.10 | |
| | 2028-2048 | " | 8.57 | 9.49 | |
| | 1915-2130 | Outlet | 4.29 | 12.58 | |
| 8/6 | 1505-1522 | Hot Zone | 8.68 | 10.48 | |
| | 1608-1624 | " | 8.35 | 10.59 | |
| | 1656-1712 | " | 8.35 | 11.03 | |
| | 1816-1836 | " | 8.12 | 11.03 | |
| | 1848-1900 | " | 8.35 | | |
| | 1902-1921 | " | 8.46 | 10.92 | |
| | 2124-2139 | " | 8.35 | 11.47 | |
| | 2228-2248 | " | 8.35 | 11.03 | |
| | 1541-1735 | Outlet | 0.79 | 16.55 | Leaked in line |
| | 1805-2040 | " | 4.74 | 14.34 | |
| | 2118-2303 | " | 4.29 | 14.56 | |
| 8/7 | 1330- | Hot zone | 8.40 | 10.69 | Preliminary stop time missed |
| | 1425-1440 | " | 8.28 | 10.15 | |
| | 1455-1510 | " | 8.28 | 10.15 | |
| | 1520-1540 | " | 7.61 | 10.79 | |
| | 1555-1610 | " | 8.71 | 9.83 | |
| | 1630-1645 | " | 8.28 | 10.58 | |
| | 1703-1715 | " | 8.28 | 10.15 | |
| | 1755-1820 | " | 8.06 | 10.69 | |
| | 1830-1845 | " | 8.28 | 10.69 | |
| | 1920-1935 | " | 8.06 | 10.90 | |

(Continued)

TABLE A1. (Continued)

| Date (1980) | Time Sampled (hrs) | Sampling Location | Results $CO_2$ % | $O_2$ % | Comments |
|---|---|---|---|---|---|
| 8/7 (cont'd) | 2015-2030 | Hot zone | 7.72 | 11.12 | |
| | 2100-2115 | " | 9.18 | 9.94 | |
| | 2130-2145 | " | 8.28 | 10.69 | |
| | 1430-1650 | Outlet | 2.46 | 15.71 | Leak in pump |
| | 1755-1820 | " | 1.12 | 16.78 | Leak in sample line |
| | 1823-1824 | " | 6.04 | 12.40 | New sample |
| | 2053-2115 | " | 5.71 | 12.18 | |
| 8/22 | 0947-1003 | Hot zone | 7.03 | 12.16 | Poor results - when test was over, found that sample probe burned off and sampled air leakage around port |
| | 1156-1217 | " | 3.05 | 14.81 | |
| | 1252-1303 | " | 2.81 | 15.23 | |
| | 0835-1000 | Outlet | 7.50 | 11.53 | |
| | 1205-1215 | " | 7.03 | 11.63 | |

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# APPENDIX B

# FIELD DATA SHEETS

The material on pages 47-92 is not suitable for reproduction.

These pages can be viewed at the Region 6 Office of the US Environmental Protection Agency

1201 Elm Street
Dallas, Texas 75270

# APPENDIX C

## PROCESS DATA

Appendix C contains all of the raw process data sheets for the three test days at Rollins (8-6-80, 8-7-80, and 8-22-80). The sheets are organized by test day. There are three different types of data sheets: The first type contains temperature, combustion gas, and fan data. The second type contains PCB feed rate data. The third type contains hour-by-hour readings of plant operations routinely taken by plant personnel. Note that no PCBs were fed during the first test day; and, hence, there are no corresponding data sheets for this day.

The first kind of data sheet contains military time, hot duct temperature, afterburner temperature, kiln temperature, ambient temperature, CO concentration, $CO_2$ concentration, $O_2$ concentration, forced air fan opening, and induced draft fan opening. All of these were taken every fifteen minutes, in the units given on the sheet. The induced draft fans were always 100% open, and the forced draft fan opening did not affect total mass flow through the incinerator. These, along with ambient temperature, were not considered important enough to discuss in the report.

The second kind of data sheet contains flow rate data for the PCB waste. Times are given as before. Column 1 gives the volume of waste in the holding tank expressed as an equivalent volume of water. This number divided by the density of the waste gives the true volume of the waste in the tank. Column 2 indicates the density of the waste in the tank. Column 3 is a direct reading of instantaneous flowrate; however, it is actually twice the real flow. It must be pointed out that the numbers in columns 2 and 3 are not accurate for test two (8-7-80) because neither of these instruments were properly calibrated at the time. They can be considered accurate for the third test day (8-22-80). An additional flow measurement was made from a mechanical flow meter on this day. These numbers, read directly in terms of flow, are given in Column 4.

The third data sheet was filled out hourly by Rollins personnel. Parameters of interest are the Venturi flow rate (flow to flexitray, in GPM), the pressure drop across the Venturi (Venturi ΔP, in inches $H_2O$), the scrubber temperature (Venturi crossover temperature, in °F), the pH of the touch-up tank, and the final discharge pH (pH F-4). Other parameters may also be of interest to some readers.

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# APPENDIX D

## CALIBRATION DATA

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# APPENDIX E

# CHAIN OF CUSTODY

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# Division 4

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# EMISSIONS TESTING DURING INCINERATION OF PCBs AT ENERGY SYSTEMS COMPANY, EL DORADO, ARKANSAS

SEPTEMBER 1981

by

T. L. Sarro, D. R. Moore, and D. G. Ackerman
TRW Inc., Environmental Engineering Division
One Space Park
Redondo Beach, Ca. 90278

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Program Manager: Alice C. Gagnon
Industrial Environmental Research Laboratory
Office of Environmental Engineering and Technology
Research Triangle Park, NC 27711

Task Officer: Philip C. Schwindt
U.S. Environmental Protection Agency
Region 6 Office
Dallas, TX. 75270

Prepared for:

U. S. Environmental Protection Agency
Office of Pesticides and Toxic Substances and
Region 6 Office
Washington, D. C. 20460

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This report has been reviewed by the Region 6 Office, Office of Toxic Substances, and the Industrial Environmental Research Laboratory, U. S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U. S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

# ABSTRACT

This report describes the emissions testing performed at and results obtained from Energy Systems Company, El Dorado, Arkansas, while polychlorinated biphenyls (PCBs) were being incinerated.

Samples were taken of all incineration system influent and effluent streams, including stack gas, PCBs fed, auxiliary fuel and waste, scrubber input, scrubber output, and treated plant effluent. Stack gas samples were taken with a Modified Method 5 Train incorporating a porous polymer adsorbent and operating isokinetically. Samples of other streams were taken manually at specified intervals. Incineration systems operating data also were acquired.

This report was submitted in fulfillment of Contract No. 68-02-3174, Work Assignment 56, by TRW Inc., Environmental Engineering Division, under sponsorship of the U. S. Environmental Protection Agency. This report covers the period July 15, 1980 to September 15, 1980 (when the testing was performed) and January 26, 1981 to February 26, 1981, and work was completed as of February 26, 1981.

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# 1. INTRODUCTION

TRW Inc., Environmental Engineering Division, under contract to the U.S. Environmental Protection Agency (Contract No. 68-02-3174, Work Assignment No. 31), performed emissions testing during incineration of polychlorinated biphenyls (PCBs) at Energy Systems Company (ENSCO), El Dorado, Arkansas. The purpose of the testing was to determine whether or not polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) were emitted from the incineration system while PCBs were being burned.

Technical direction of the sampling effort was provided by the U.S. Environmental Protection Agency's (EPA) Region 6 Office in Dallas, Texas. Mr. Philip C. Schwindt of Region 6 was the Technical Officer for the Work Assignment. Technical details were coordinated with the following organizations:

- EPA's Office of Pesticides and Toxic Substances, Washington, DC, Mr. Bill Gunter, Mr. Glenn Kuntz, and Dr. Don Barnes
- EPA's Special Pesticide Review Division, Arlington, VA, Mr. Mike Dellarco
- EPA's Health Effects Research Laboratory, Research Triangle Park, NC, Dr. Bob Harless, Dr. Bob Lewis, and Mr. Merrill Jackson
- Wright State University's Brehm Laboratory, Dayton, OH, the analysis contractor to EPA, Dr. Tom Tiernan
- ENSCO, El Dorado, AK, Dr. George Combs

At TRW, this effort was managed by Dr. Don Ackerman. Mr. Dave Moore was the field team leader, and Mr. Tom Sarro was the field engineer.

Samples were taken of all incineration system influent and effluent streams, including stack gas, PCB feeds (liquid and shredded capacitors), auxiliary feed and waste feeds, scrubber inlet solutions, scrubber outlet solutions, and solid residues from the incinerator. Testing was completed during the period 25-29 August 1980.

The following chapters and appendices of this report describe the testing performed and results obtained: Chapter 2, Summary; Chapter 3, Facility Description; Chapter 4, Sampling and Monitoring; Chapter 5, Technical Problems and Recommendations: Appendix A, Gaseous Monitoring; Appendix B, Field Data; Appendix C, Process Data; Appendix D, Calibration Data; and Appendix E, Chain of Custody Forms.

## 2. SUMMARY

### 2.1 SAMPLING

The field test effort at Energy System Company (ENSCO) took place during the period 25-29 August 1980. All required tests were completed and all recovered samples were sent to Wright State University for analysis.

Duplicate stack tests were taken during its incineration of the following fuel types and incinerator conditions:

- Test 1 - Blended liquid organic wastes, sludges, (ink and paint) and non-PCB containing capacitors with the incinerator at normal burn rate and operational temperatures.
- Test 2 - Blended liquid organic wastes, PCB capacitors and liquid in place of the sludge. Incinerator operation was at 1200± 100°C, $O_2 > 3\%$ and CO content of < 50 ppm.
- Test 3 - PCB capacitors, liquid PCBs, and fuel oil in place of organic wastes. Incinerator operating as in Test 2.

Duplicate sets of composite samples were taken from each liquid, solid or slurry stream.

Gaseous ($CO_2$, $O_2$) monitoring was performed at the stack only. ENSCO personnel monitored CO and $O_2$ at the "hot" or inlet zone.

A daily field test summary is presented in Table 1. A summary of the reduced data on a daily basis, as calculated from the field data sheets, is presented in Table 2. The data listed in Table 2 have been corrected to standard conditions of 20°C and a barometric pressure of 1 atmosphere (760 mm Hg) as necessary. Tables 3 and 4, respectively, present descriptions of the gaseous and solid/liquid samples collected and their respective sampling frequencies.

### 2.2 PROCESS MONITORING

All parameters critical to the safe operation of the incinerator were monitored once every 15 minutes during the three tests. Among these parameters are those for which requirements have been established by EPA. These include

TABLE 1. DAILY FIELD TEST SUMMARY

| Date (1980) | Test No. | Sampling Locations | Test Comments |
|---|---|---|---|
| 8/26 | 1 | Outlet-Train 1 | Test started at 1235 hrs. and ran for 240 minutes. Numerous leak problems, broken glassware and plugged XAD-2 traps - all corrected and test quality is good. |
| | | Outlet-Train 2 | Test started at 1240 hours and ran for 240 minutes. Numerous leak problems, broken glassware and lugged XAD-2 trap - All problems corrected and list quality is good. |
| | | Gaseous Monitoring | No problems. Test quality is good. |
| 8/27 | 2 | Outlet-Train 1 | Test started at 1115 hours. Last meter box pump at 1120 hours. Restarted at 1155 hours and ran for total of 240 minutes. Test quality is good. |
| | | Outlet-Train 2 | Test started 1200 hours and ran for 240 minutes. Test quality is good. |
| | | Gaseous Monitoring | No problems. Test quality is good. |
| 8/28 | 3 | Outlet-Train 1 | Test started at 0915 - Florisil trap plugged - It was replaced and test ran for total of 240 minutes. Test quality is good. |
| | | Outlet-Train 2 | Test started at 1010 hours and ran for 240 minutes. Test quality is good. |
| | | Gaseous Monitoring | No problems - Test quality is good. |

## TABLE 2. DAILY DATA SUMMARY

| DATE | TEST NO. | SAMPLING LOCATION | SAMPLE VOLUME DSCF | SAMPLE VOLUME $Nm^3$ | GAS COMPOSITION $O_2$ % | GAS COMPOSITION $CO_2$ % | GAS COMPOSITION CO ppm | STACK TEMP °F | MOLECULAR WEIGHT | MOISTURE % | VELOCITY ft/sec | GAS FLOW ACFM | GAS FLOW DSCFM | ISOKINETIC RATE % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8-26-80 | 1 | Train 1 | 128.264 | 3.6 | 12.2 | 5.7 | -- | 164.3 | 25.41 | 35.00 | 10.73 | 45268.418 | 24917.991 | 109.8 |
|  |  | Train 2 | 105.481 | 3.0 | 12.2 | 5.7 | -- | 163.3 | 25.57 | 33.53 | 9.86 | 41940.631 | 23462.344 | 93.2 |
| 8-27-80 | 2 | Train 1 | 99.545 | 2.8 | 13.3 | 6.2 | -- | 165.5 | 25.46 | 35.24 | 9.23 | 39271.273 | 21319.614 | 99.6 |
|  |  | Train 2 | 94.782 | 2.7 | 13.3 | 6.2 | -- | 156.4 | 25.50 | 34.90 | 9.15 | 38931.486 | 21585.364 | 95.9 |
| 8-28-80 | 3 | Train 1 | 92.629 | 2.6 | 13.2 | 5.5 | -- | 164.6 | 25.41 | 35.05 | 9.00 | 38265.277 | 20892.293 | 94.6 |
|  |  | Train 2 | 91.646 | 2.6 | 13.2 | 5.5 | -- | 164.1 | 25.40 | 35.09 | 8.51 | 36184.475 | 19756.408 | 101.3 |

* Dry standard cubic feet of flue gas sampled (20°C, 1 atmosphere).

+ Normal cubic meters of flue gas sampled (20°C, 1 atmosphere).

TABLE 3. GASEOUS SAMPLING SCHEME

| Frequency | Sample Description | Sample For | Sampled By | Analyzed By |
|---|---|---|---|---|
| 4 hours | Stack gases | PCB<br>dibenzodioxin<br>dibenzofurans | TRW | Wright State University |
| Continuous | Flue gas | $O_2$ | ENSCO | ENSCO |
| Continuous | Flue gas | CO | ENSCO | ENSCO |
| 120 minutes | Flue gas | $CO_2$<br>$O_2$ | TRW | TRW |

TABLE 4. SOLID/LIQUID SAMPLING SCHEME (ENSCO)

| Stream | Sampling Frequency | Total Samples 4-hour Test Period) | Sample Quantity* | Composite Storage Size/Type+ |
|---|---|---|---|---|
| LIQUIDS | | | | |
| • Liquid PCB Feed | 15 minutes | 16 | 250 ml per sample | Half-gallon amber glass |
| • Liquid Waste Feed | 30 minutes | 8 | 250 ml per sample | Half-gallon amber glass |
| • Well Water | 30 minutes | 8 | 250 ml per sample | Half-gallon amber glass |
| • Scrubber Liquor | 30 minutes | 8 | 250 ml per sample | Half-gallon amber glass |
| • Recycled Scrubber Liquor | 30 minutes | 8 | 250 ml per sample | Half-gallon amber glass |
| • Caustic Solution | 30 minutes | 8 | 250 ml per sample | Half-gallon amber glass |
| • Lime Slurry | 30 minutes | 8 | 250 ml per sample | Half-gallon amber glass |
| SOLIDS | | | | |
| • Shredded Capacitors | 14 minutes | 16 | 1 pint per sample | 1 gallon steel can |
| • Kiln Ash | 30 minutes | 8 | 1 quart per sample | 250 ml amber glass |

** Duplicate samples were collected from streams.

†† 500 ml aliquot of composited PCB feed and shredded capacitors were removed from composite storage containers and provided to ENSCO.

# Samples were taken approximately one-half hour to one and one-half hours after the other samples to allow for the residual time of the capacitors in the kiln between the time they entered the kiln to the time they reached the sampling location at the exit from the kiln.

the combustion chamber (thermal oxidation unit, TOU) temperature, concentrations of $O_2$ and CO, and the PCB fuel feed rate. $CO_2$ was also monitored because it is required to calculate the combustion efficiency, which also is a required parameter. Residence time, also a required parameter, is strongly related to the volume of the combustion zone to the temperature within that region and less strongly to the amount of excess air in the combustion zone. All of these parameters, and also the kiln temperature, have been summarized on a daily average basis for the three test days in Table 5. Table 6 presents the minima and maxima for these same parameters, based on the 15-minute instantaneous values. Raw data have been included in Appendix C.

The average TOU temperature during the three tests was 2239°F (1226°C). This is well above the minimum value of 2012°F (1100°C) required by EPA (40 CFR 761.40). In fact, this temperature never fell below 2150°F (1177°C) during the entire sequence of tests. Similarly, the residence time of the process never fell below 2 seconds, well above the minimum allowable (40 CFR 761.40). Residence times on the order of 4 seconds or above were typical, and the lowest instantaneous value was 3.27 seconds. No problems were encountered with any of the temperature instrumentation.

Continuous monitors were used to measure oxygen and carbon monoxide levels. A gas chromatograph was also available to measure carbon dioxide, so that all of these values were recorded on a 15-minute basis. All of the analyzers performed well, as evidenced by the generally small standard deviations for CO, $CO_2$, and $O_2$ (evidence also for stable combustion). The only exception was a period of high CO values during the background (first) test. A CO spike occurred (Table 6) in which the highest recorded value was 150 ppm. This explains the unusually high standard deviation for CO on this day. While PCBs were being burned, 50 ppm was the highest allowable CO concentration without requiring shutdown of PCB feed. It can be seen that CO never exceeded 4.5 ppm during the two PCB tests. The average $CO_2$ concentration over all three tests was 5.9%, the range extending from 3.5 - 10.0%. The lowest acceptable $O_2$ value for this facility was 4.5%, and the lowest $O_2$ value measured was 8.0%. Combustion efficiency is a function of CO and $CO_2$ concentrations. The lowest instantaneous combustion efficiency was 99.7506%, occurring simultaneously with the 150 ppm CO spike during the background test. The lowest value encountered

## TABLE 5. COMBUSTION PARAMETERS FOR THE THREE TEST DAYS

| Parameter | Test One, 8-26-80 Background Fuel | | Test Two, 8-27-80 PCB & Background Fuel | | Test Three, 8-28-80 PCB & Fuel Oil | |
|---|---|---|---|---|---|---|
| | $\overline{X}$+ | s+ | $\overline{X}$ | s | $\overline{X}$ | s |
| TOU Temperature | 2234°F | 42.84 | 2235°F | 30.96 | 2247°F | 28.89 |
| | 1223°C | -- | 1224°C | -- | 1231°C | -- |
| Kiln Temperature | 1375°F | 95.74 | 1360°F | 80.46 | 1412°F | 127.66 |
| | 746°C | -- | 738°C | -- | 767°C | -- |
| $O_2$ (%) | 11.2 | 1.06 | 12.7 | 0.86 | 12.6 | 1.34 |
| $CO_2$ (%) | 6.0 | 1.54 | 6.1 | 1.22 | 5.7 | 1.56 |
| CO (ppm) | 12.8 | 29.21 | 1.6 | 1.46 | 0.76 | 0.87 |
| Combustion Efficiency (%) | 99.9779 | 0.0489 | 99.9970 | 0.0046 | 99.9988 | 0.0052 |
| Residence Time (Seconds) | 2.60 | 0.42 | 2.80 | 0.43 | 2.54 | 0.61 |
| Liquid PCB Feed Rate* | 0 | -- | 520 lb/hr<br>236 kg/hr | --<br>-- | 459 lb/hr<br>208 kg/hr | --<br>-- |
| PCB Capacitor Feed* Rate | 0 | -- | 1213 lb/hr<br>546 kg/hr | --<br>-- | 1128 lb/hr<br>512 kg/hr | --<br>-- |

* Total Flow. Exact PCB content of these materials will be known pending laboratory analysis.

+ $\overline{X}$ and s are, respectively, the average and standard deviation.

TABLE 6. MAXIMUM AND MINIMUM VALUES OF COMBUSTION PROCESS PARAMETERS

| Parameter | Test One, 8-26-80 Background Fuel |  | Test Two, 8-27-80 PCB & Background Fuel |  | Test Three, 8-28-80 PCB & Fuel Oil |  | PCB Mode Operation (Tests Two & Three) |  |
|---|---|---|---|---|---|---|---|---|
|  | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min. |
| TOU Temperature | 2350°F<br>1288°C | 2150°F<br>1177°C | 2300°F<br>1260°C | 2180°F<br>1193°C | 2300°F<br>1260°C | 2200°F<br>1204°C | 2300°F<br>1260°C | 2180°F<br>1193°C |
| Kiln Temperature | 1500°F<br>816°C | 1300°F<br>704°C | 1500°F<br>816°C | 1150°F<br>621°C | 1725°F<br>941°C | 1150°F<br>621°C | 1725°F<br>941°C | 1150°F<br>621°C |
| $O_2$ (%) | 13.0 | 8.0 | 13.5 | 10.5 | 14.7 | 8.0 | 14.7 | 8.0 |
| $CO_2$ (%) | 10.0 | 3.5 | 8.3 | 4.5 | 10.0 | 3.5 | 10.0 | 3.5 |
| CO (ppm) | 150.0 | 0 | 4.5 | 0 | 4.0 | 0 | 4.5 | 0 |
| Combustion Efficiency (%) | 99.9999 | 99.7506 | 99.9999 | 99.9900 | 99.9999 | 99.9954 | 99.9997 | 99.9900 |
| Residence Time (Seconds) | 2.49 | 2.68 | 2.73 | 2.86 | 2.49 | 2.58 | 2.86 | 2.49 |

during the PCB incineration tests was 99.99%, above the 99.9% required by EPA.

PCB feed rates can only be given in terms of total mass flow of those wastes containing PCB, since the exact PCB content of these materials is not yet known. No PCBs were fed during the background test (first test day). Feed rates for PCB liquid (actually an oil) were 236 kg/hr (520 lb/hr) and 208 kg/hr (451 lb/hr) for the second and third test days. The corresponding rates of solid PCB capacitors were 550 kg/hr (1213 lb/hr) and 512 kg/hr (1128 lb/hr).

Other mass flow rates through the incinerator facility are also of interest. The total fuel flow rates were 2244 kg/hr (4948 lbs/hr), 2177 kg/hr (4800 lbs/hr), and 1650 kg/hr (3637 lbs/hr), respectively, for the three test days. Amounts of injected water ranged from 1424 to 2150 kg/hr (3140 to 4740 lbs/hr) and mass flow rates of ambient air were on the order of 39,000 kg/hr (85,000 lbs/hr). Consumption of caustic solution by the scrubber ranged from 945 kg NaOH/hr (2084 lbsNaOH/hr) for the second test day to 372 kg NaOH/hr (821 lbs NaOH/hr) for the third test day. This is logical since fuel oil was used instead of chlorinated organic waste on the third day, drastically reducing the chlorine content of the composite fuel for that day.

## 3. FACILITY DESCRIPTION

The facility described in this section is a hazardous waste incinerator operated by the Energy Systems Company (ENSCO), El Dorado, Arkansas. This system represents the state of the art for thermal destruction of hazardous wastes. High destruction efficiency and wet scrubbing of the flue gas minimize environmental impacts from plant operation. This description is based on on-site observations, numerous conversations with ENSCO personnel, and a previously prepared test report (1). Figure 1 shows a schematic of the incineration process.

### 3.1 WASTE FEED FACILITIES

The equipment in use at ENSCO is capable of handling a large variety of liquid, solid, and semi-solid wastes. A shredder and hammermill are used to reduce objects as large as utility capacitors to very small pieces which will burn easily. Liquid wastes can be piped from large tanks or pumped out of smaller containers, such as 55 gallon drums. The drums can be steam cleaned or destroyed by the shredder and incinerated.

Shredding prepares solid objects for incineration in a rotary kiln. Two hammermills are employed in series to produce fragments roughly 0.5 inch square. The primary hammermill, rated at 30 Hp, is mounted directly over the secondary hammermill, rated at approximately 50 Hp. Solids (such as electronic capacitors) are stored in 55 gallon drums. Each drum is weighed and hoisted up to the level of the primary hammermill, where an operator slowly empties the barrel into a hopper. Shreddings from the primary hammermill fall through the secondary hammermill and collect on the bottom of the shredder enclosure in a form referred to as "fluff". The fluff is deposited into the rotary kiln through a screw worm auger. Release of PCBs from the shredding operation is minimized by maintaining the hammermill hoppers at subtamospheric pressure (0.1-0.2 inches $H_2O$ or 0.019-0.037 cm Hg). This subatmospheric pressure is

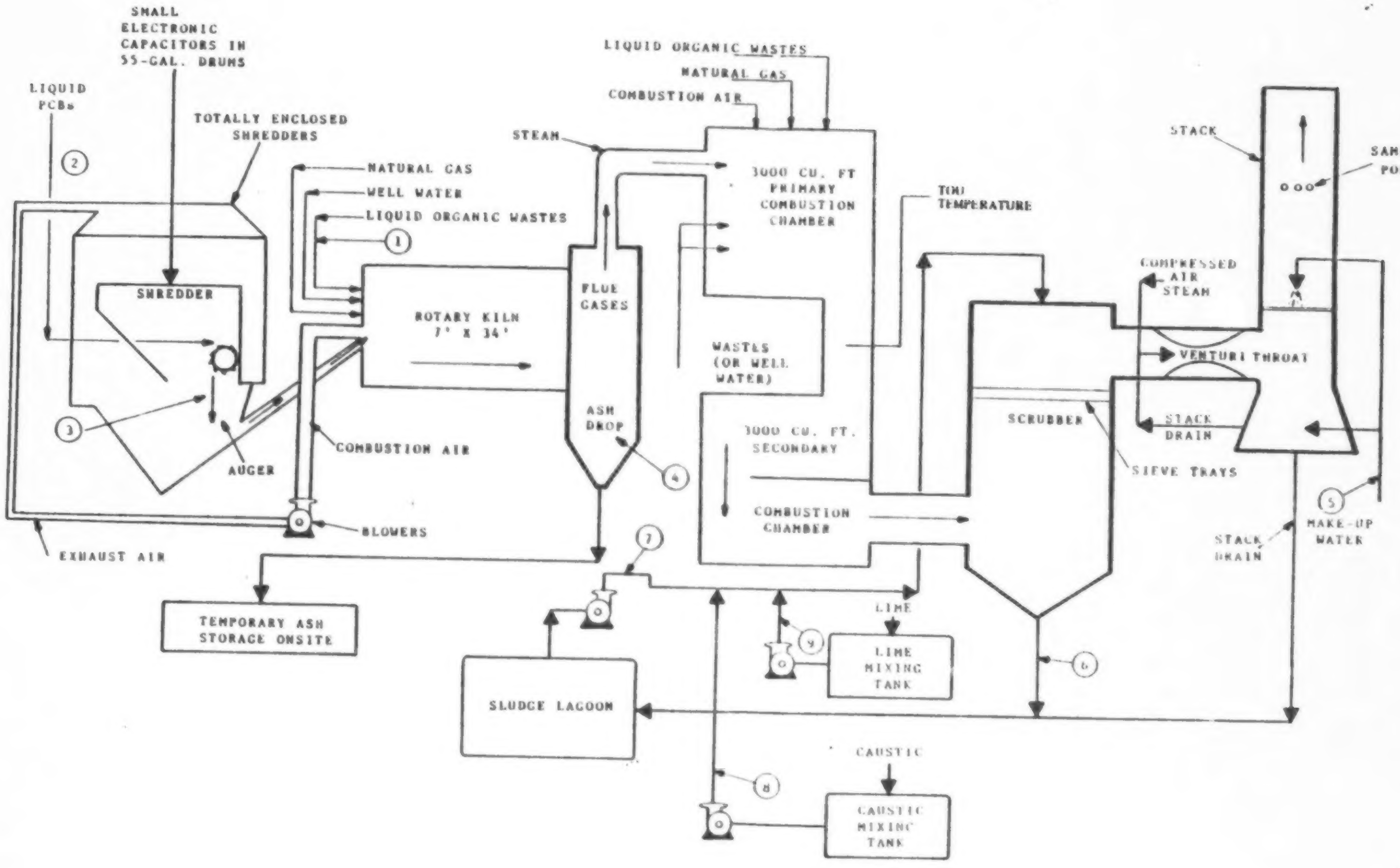

Figure 1. Schematic of incineration system at ENSCO.

maintained by a blower (rated 3000 cfm at 1 psi) which exhausts into the rotary kiln, providing a source of combustion air for incineration of the solids.

Most liquid wastes can be fired directly into any of several burners in the incineration system. However, very hazardous wastes such as PCBs are fed only into the rotary kiln because this affords a somewhat longer residence time. Such wastes are stored in drums which are opened one at a time, eliminating the possibility of a widespread spill. Liquid PCB feed is accomplished by placing a full 55 gallon drum onto a scale. The cap is removed from the drum and a hand operated gravity fed pump developing up to 50 psi of suction is used to draw the liquid out. The pump operator can feed a given rate of liquid PCB by watching the weight change on the scale and turning the pump on or off as necessary. Rather than injecting this liquid directly into the kiln, it is first mixed with the fluff settling on the bottom of the shredder enclosure. Thick organic liquids such as PCBs adsorb readily onto the fluff, so that there is no residual liquid in the fluff mixture that is brought into the kiln by the auger.

Heavy, non-solid materials such as sludges can be fed manually through a door at the base of the shredder enclosure. These would then be lifted into the rotary kiln by the auger. The opening is large enough to accommodate a 55 gallon drum, so that waste drums can be cleaned by placing them upside down into the enclosure and applying a high pressure steam jet to the inside of the drum.

## 3.2 INCINERATOR

The incinerator is comprised of three combustion units in series. These are the rotary kiln, the primary combustion chamber, and the secondary combustion chamber. All have refractory linings and maintain temperatures adequate for the destruction of even the most stable compounds. The greatest volume of liquid wastes are fired into the primary combustion chamber. The kiln is primarily intended for destruction of solids although liquids are also fired there.

Fluff from the shredding operation is carried by the auger into the front of the kiln. This unit is 34 feet long, has a 7 foot inside diameter, and rotates once every two minutes. The internal geometry of the kiln is such that solids will be "turned over" as they traverse its length. Retention times are approximately 60 minutes for solids and 3.7 seconds for gases. In addition to solid fluff, natural gas, water, and liquid organic waste can be fired in the kiln. It is desirable to maintain a temperature of 1300°F (704°C), and the flow rate of liquid organic waste can be adjusted accordingly. A control console is located near the front of the kiln, where an operator can monitor kiln temperature, kiln draft, draft at the top of the primary hammermill, and pressure drop across the auger. An ash drop at the opposite end collects the solid residue, and a drag chain lifts it out into containers for disposal.

Gases leaving the rotary kiln are literally pushed into the primary combustion chamber by a jet of steam situated so as to impart momentum to the gas stream (steam ejector). The primary combustion chamber and afterburner make up a pair of identically shaped furnaces connected by a crossover duct. In addition to liquid waste, natural gas, water, or aqueous waste may be fired in the first chamber, where essentially complete combustion takes place. Ambient air inlets are also provided here to insure adequate excess oxygen levels.

Any ash content of the fuel collects on the furnace floor in molten state and can be removed by a slag tap. A thermocouple is mounted in the crossover duct, and this is taken as a conservative measure of temperature in the primary combustion chamber. This is the temperature reading used to satisfy EPA requirements for monitoring of the incineration process.

The secondary chamber functions to increase residence time of the combustion gases and thus insure maximum destruction efficiency. This chamber is baffled to promote thorough mixing. A thermocouple mounted at the outlet of the secondary chamber measures the lowest temperature. This is roughly 300°F lower than the primary combustion chamber (crossover duct), which is usually maintained a few degrees above the EPA recommended value of 2192°F. These temperatures, as well as the crossover duct draft, are monitored in the plant's control room. The combustion chambers have internal volumes of about 3000 cubic feet (85 m$^3$) each, which provides a total residence time of approximately 4.5 seconds in both combustion chambers.

## 3.3 SCRUBBER AND DISCHARGE SYSTEM

Combustion gas leaving the secondary chamber is cooled by a liquid quench, enters the wet scrubber, and eventually exits through the stack. The scrubber is a closed-cycle system in which spent scrubber liquor is discharged to a settling lagoon and clarified surface water is recycled to the scrubber. There is no surface water discharge from the lagoon. A vertical tower scrubber is used, and although there is a Venturi device followint the tower, its principal function is not to scrub the flue gas but to provide draft for the incineration system.

Combustion gases leaving the secondary chamber enter a quench section at the bottom of the scrubber tower. Quenched gases pass up through the tower, and recycled scrubber liquor is sprayed down from the top. A series of sieve trays are coated with the flow of scrubber liquor and provide a large contact area between the combustion gas and the highly alkaline scrubber liquor. Thus, acids in the gas dissolve into the liquid and are neutralized (particularly HCl). Particulates are entrained into the liquor phase. Liquid collecting on the bottom of the scrubber is also used as the quench, is ultimately drained off as spent scrubber liquor, and flows by gravity to the sludge lagoon.

Solids settle out to the bottom of the sludge lagoon. The relatively clear surface water is treated with lime and/or caustic solution to restore proper alkalinity and then pumped back into the scrubber tower.

After leaving the scrubber, gases enter a duct 25 feet long which connects the scrubber to the base of the stack. This duct contains a high velocity jet which points directly into the converging section of a Venturi throat. Compressed air, steam, and stack drain liquid are injected into the gas stream. The gas stream is entrained into this "liquid jet" and acquires some of its velocity. The Venturi converges very rapidly, then diverges gradually so that the velocity energy of the gas is transformed into pressure energy which provides a driving force for release through the stack. A measurement of jet draft (typically 12 cm Hg or 6 in $H_2O$) is taken just before the gas stream reaches the point of jet release. Gas samples for the CO and $O_2$ monitors are withdrawn in the duct between the scrubber and compressed air jet.

Although the principal purpose of the Venturi is to provide draft, some scrubbing occurs here. For instance, the steam provides a supersaturated atmosphere so that water vapor will condense on submicron size particles, increasing their mass and thus facilitating removal from the gas stream. The converging section of the Venturi promotes agglomeration of small liquid particles so that they can be removed by gravitational forces.

Flue gas exits the Venturi duct and rises to escape through the stack. Large liquid droplets fall quickly to the bottom of the stack and are drawn off to the sludge lagoon. A demister pad mounted inside of the stack captures any small liquid particles remaining in the gas stream. A spray of fresh water is maintained over the top of the demister pad to keep it clean and to inhibit any upward motion of the water collecting on it. Make-up water for the entire system is added at the bottom of the stack. The pressure drop across the demister pad is 0.1 inches water. The stack pressure on top of the demister pad is -0.5 inches water (-0.09 cm Hg).

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# 4. SAMPLING AND MONITORING

## 4.1 STACK GAS SAMPLING

### 4.1.1 Sampling Locations

All sampling locations are identified in Figure 1. Figure 2 is a schematic of the stack, including a cross sectional view depicting the traverse point locations.

The inorganic gas samples for molecular weight determination were taken at the stack sampling locations. ENSCO monitored the gases for CO and $O_2$ at a point between the scrubber and the compressed air jet.

### 4.1.2 Sampling Train Description

The PCB sampling train, shown schematically in Figure 3, was utilized to collect the organic constituents of the flue gas. The PCB train is a modification of a standard EPA Method 5 train. A solid sorbent trapping system was incorporated downstream of the probe and between the third and fourth impinger. By placing the sorbent traps in this position, the gas stream was relatively dry as moisture was condensed in the first two water filled impingers. Granular XAD-2 resin was used for the primary sorbent material. As a backup to XAD-2, Florisil was used to adsorb any residual organics or organochlorine compounds that may break through the XAD-2 trap. The two sorbent traps are water jacketed, (Figure 4), and an exiting gas temperature of 16°C (60°F) was maintained by recirculating the impinger ice bath water through the jackets. Because of the sensitivity of organics to ultraviolet light, the sorbent traps were wrapped in aluminum foil, while the impingers and interconnecting glassware were shielded from light.

### 4.1.3 Operating Procedures

Sampling for organics was done concurrently at the stack outlet location utilizing the PCB train. Two identical samplng trains were operated at a rate

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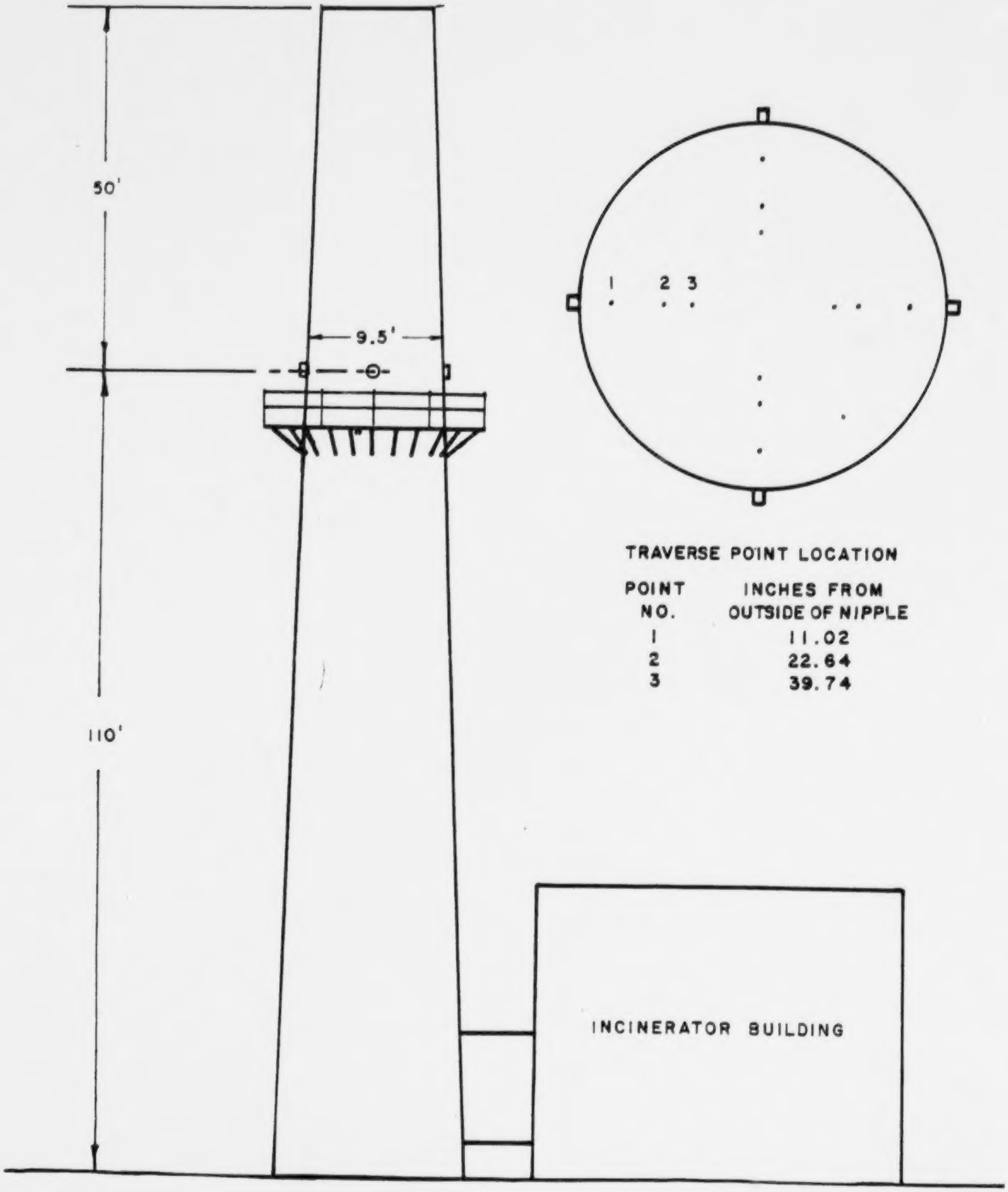

TRAVERSE POINT LOCATION

| POINT NO. | INCHES FROM OUTSIDE OF NIPPLE |
|---|---|
| 1 | 11.02 |
| 2 | 22.64 |
| 3 | 39.74 |

Figure 2. Schematic of ENSCO's stack and sampling points.

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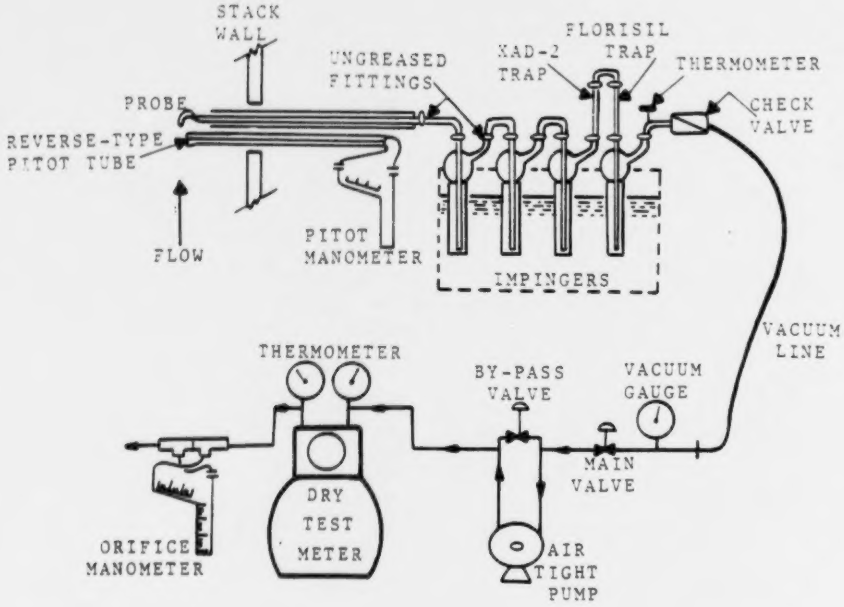

Figure 3. Schematic of PCB sampling train.

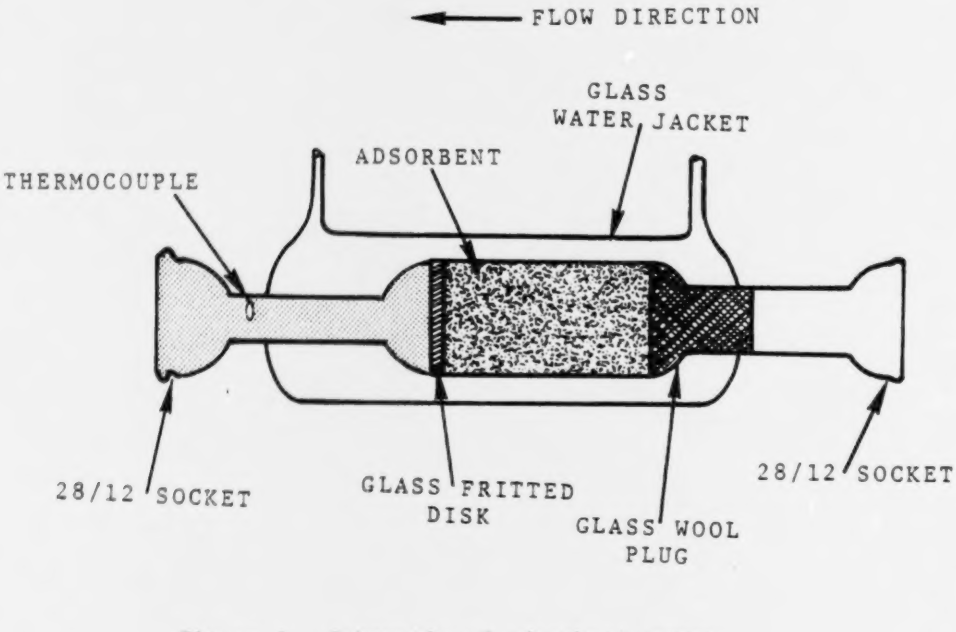

Figure 4. Schematic of adsorbent traps.

approximating the flue gas velocity (isokinetically according to EPA Method 5, 40 CFR 60). The gas stream was passed through the impinger solutions (water) to condense any moisture present in the stack gas and to remove all particulate matter and any associated organics. The gas stream then passed through the sorbent traps to adsorb the remaining organic constituents. Process parameters such as temperatures, pressures, gas volumes were monitored throughout each sampling period.

Prior to test initiation, the sampling trains were leaked checked at 15 inches mercury. If a leak rate greater than 0.02 cfm was present, the sampling train was systematically checked to find the leak. No train was operated with an unacceptable leak rate. No grease was used on any of the glass fittings. Post-test leak checks were performed at the highest vacuum encountered during the sampling time. Leak checks were also performed prior to each port change or any disassembly of the train.

The sampling time was of 240 minutes duration and at a sampling rate of less than 0.75 cfm.

### 4.1.4 Sample Recovery

Upon completion of testing, each train was removed to a clean area (mobile laboratory) for recovery. Each train was recovered separately to prevent sample mix-up and cross contamination. Each train component was recovered per the following:

- Probe and nozzle were wiped to remove residual particulate.
- After recovering dry particulate from the nozzle and probe, these parts were rinsed with acetone and hexane. Rinsate was retained in an amber glass bottle (labeled, then sealed).
- Florisil and XAD-2 resin traps were removed from the train, capped, and then wrapped for shipment to the analysis laboratory.
- Impingers - each of the impingers was weighed, weights were recorded, and contents were transferred to amber glass bottles. The impingers were then rinsed with small amounts of acetone and hexane. Rinses were combined with the impinger catch, and rinse volumes were recorded.
- Silica gel impingers were weighed, recorded, and regenerated for subsequent use.

- All retained samples were sealed and labeled with an EPA Chain of Custody tags.
- PCB feed samples were not brought into the van for recovery in order to prevent contamination of the train samples.

## 4.2 LIQUID STREAM SAMPLING

This section summarizes the liquid sampling locations, the procedures used to collect these samples, and the methods by which the samples were recovered.

### 4.2.1 Sampling Locations

The location of the sampling points can be seen in Figure 1. A description of each sampling point is presented in the following subsections:

- Liquid Organic Waste - Sample Stream 1 - Samples of the chlorinated organic waste stream were taken from a valve in the pipeline prior to introduction into the rotary kiln.
- Liquid PCBs - Sample Stream 2 - Liquid PCBs were pumped into the hammermill hopper before the auger system. Samples were taken from the line running between the liquid PCB containers and the hammermill.
- Well Water - Sample Stream 5 - Well water samples were taken from a valve in the pipeline leading to the scrubber.
- Scrubber Liquor - Sample Stream 6 - Spent venturi scrubber liquor samples were collected from an open portion of the pipeline transporting the liquor to the sludge lagoon.
- Recycled Scrubber Liquor - Sample Stream 7 - Recycled scrubber liquor samples were taken directly from the pipeline leading to the scrubber.
- Caustic Solution - Sample Stream 8 - Caustic solution samples were collected from the pipeline leading from the caustic tank to the venturi scrubber.
- Lime Slurry - Sample Stream 9 - Lime slurry samples were collected from a valve in the pipeline leading from the lime mixing tank to the scrubber.

### 4.2.2 Operating Procedures

Table 4 illustrates that sampling frequencies and sample quantities were the same for all of the liquid streams except the liquid PCB feed. The difference with the liquid PCB stream was that it was sampled twice as often (15-minute intervals). This was done because there was no premixing of capacitors, and a wide variation in PCB concentration was expected. Liquid stream sampling frequencies were performed at times concurrent with stack sampling.

Each liquid process stream (liquid PCB feed, liquid waste feed, well water, recycled scrubber liquor, scrubber liquor, lime slurry and caustic solution) sample was collected in a hexane rinsed amber glass bottle (250 ml) and transferred to a hexane rinsed amber glass bottle (1/2 gal) to obtain a composite sample for each test. Duplicate sets of composite samples were obtained for each type stream.

## 4.3 SOLID STREAM SAMPLING

This section summarizes the solid sampling locations, the procedures used to collect these samples, and the methods by which these samples were recovered.

### 4.3.1 Sampling Locations

The location of the sampling points is shown in Figure 1. A description of each site is presented below:

- Shredded Electronic Capacitors - Sample Stream 3 - Samples of the shredded electronic capacitors (fluff) were collected from the hammermill hopper prior to the fluff falling into the auger feed system.
- Rotary Kiln Ash - Sample Stream 4 - The rotary kiln ash samples were taken directly from the ash hopper.

### 4.3.2 Operating Procedures

Table 4 illustrates the sampling frequencies and quantities of samples collected. Solid sampling frequencies were performed concurrent with stack sampling.

### 4.3.3 Sample Recovery

The shredded solid capacitor samples were collected in a new, hexane rinsed 1-pint steel can and composited in a new hexane rinsed 1-gallon steel can. Duplicate sets of composite samples were obtained. The rotary kiln ash was sampled with a hexane rinsed steel can (1 qt) attached to a clean steel handle. The individual samples of ash were composited in a hexane rinsed, galvanized steel can (20 gal). At the end of each sampling test, a composite sample was mixed by rolling the 20-gallon can. This method of mixing prevented the sample from becoming contaminated by a stirring rod. Duplicate 250-ml samples of the mixed ash were then transferred to hexane-rinsed amber glass bottles.

Each solid/liquid sample container was labelled prior to sample collection to avoid mislabeling. Following sample collection, each container was sealed, tagged, and packaged in accordance with EPA Chain of Custody procedures. The samples were shipped to Wright State University for analysis via various freight carriers. Each sample set was sent via a different carrier to prevent all samples from being lost or damaged in the same shipment.

## 4.4 PROCESS MONITORING

While the three tests were being performed, records were kept of operating parameters within the incinerator plant. These included temperatures, combustion gas concentrations, waste feed rates, and scrubber operations as described in subsequent subsections. Calculations for residence time and combustion efficiency are also presented.

The information presented here has been reduced from the raw data sheets included in Appendix C. Means and standard deviations have been calculated for each test day whenever possible. In most cases the data were recorded at 15 minute intervals. Any exceptions have been noted.

### 4.4.1 Temperature

Four temperatures were monitored on a 15-minute basis: thermal oxidation unit (TOU), combustion chamber outlet, kiln, and scrubber. All were measured with thermocouples, which provided signals to strip chart recorders in the central control room. TOU temperatures were measured in the passageway between the primary and secondary combustion chambers (Figure 1). Outlet temperatures were measured in the duct leading to the scrubber from the secondary combustion chamber. Kiln temperatures were measured in the front of the kiln. Scrubber temperatures were measured just below the sieve trays in the scrubber. No problems occured with any of the temperature instrumentation throughout the three day test period.

Table 7 provides a summary of all temperature data for the three test days. The TOU passageway is the location for determining whether EPA incineration criteria (temperature and residence time) are being met. The minimum acceptable temperature was 1100°C (2012°F) while PCBs were being burned, without requiring

## TABLE 7. SUMMARY OF TEMPERATURE DATA

| Location of Temperature Measurement | | Test One, 8-26-80 Background Fuel | | | | | Test Two, 8-27-80 PCB & Background Fuel | | | | | Test Three, 8-28-80 PCB & Fuel Oil | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | x̄* | s* | n* | Max | Min | x̄ | s | n | Max | Min | x̄ | s | n | Max | Min |
| TOU Passageway | °F | 2234 | 42.84 | 30 | 2350 | 2150 | 2235 | 30.96 | 29 | 2300 | 2180 | 2247 | 28.89 | 29 | 2300 | 2200 |
| | °C | 1223 | - | - | 1288 | 1177 | 1224 | - | - | 1260 | 1193 | 1231 | - | - | 1260 | 1204 |
| Combustion Chamber Outlet (Scrubber Inlet) | °F | 1773 | 55.78 | 30 | 1825 | 1500 | 1775 | 19.59 | 29 | 1810 | 1720 | 1805 | 28.88 | 29 | 1900 | 1720 |
| | °C | 967 | - | - | 996 | 816 | 966 | - | - | 988 | 938 | 985 | - | - | 1038 | 938 |
| Kiln | °F | 1375 | 95.74 | 4 | 1500 | 1300 | 1360 | 80.46 | 29 | 1500 | 1150 | 1412 | 127.66 | 26 | 1725 | 1150 |
| | °C | 746 | - | - | 816 | 704 | 738 | - | - | 816 | 621 | 767 | - | - | 941 | 621 |
| Scrubber Tower | °F | 162 | 4.31 | 30 | 175 | 158 | 162 | 2.45 | 29 | 171 | 160 | 161 | 4.23 | 29 | 170 | 151 |
| | °C | 72 | - | - | 79 | 70 | 72 | - | - | 77 | 71 | 72 | - | - | 77 | 66 |

* x̄, s, and n are, respectively, the mean, standard deviation, and number of data points.

shutdown of PCB feed. It can be seen that this temperature never fell below 1193°C (2180°F) while PCBs were being incinerated. Outlet temperatures were somewhat lower than TOU temperatures, falling in the range between 816-1038°C (1500-1900°F). Kiln temperatures ranged from 621°C-941°C (1150°F to 1725°F). Temperatures downstream of the quench (scrubber tower) were roughly 66-79°C.

### 4.4.2 Combustion Gas Concentrations & Combustion Efficiency

Levels of $O_2$, $CO_2$, and CO in the combustion gas were determined every 15 minutes by reading continuous monitors or by performing simple analyses in the control room. An electrolytic fuel cell type analyzer (Ecolyzer Model 3103) was used to measure CO levels. An automatic shutoff device was set to stop PCB flow to the kiln if this instrument read a CO level higher than 50 ppm. Oxygen was also measured continuously by a paramagnetic type analyzer (Taylor-Servomax Model OA-289). Both of these instruments supplied signals to strip chart recorders. Carbon dioxide was measured using a Fyrite analyzer, a small instrument which contained a column of liquid selectively absorptive for $CO_2$. Sample gas was drawn from the scrubber tower, so that $CO_2$ measurements are all for "clean" flue gas.

Tables 5 and 6 present all the summarized data for CO, $CO_2$, and $O_2$. CO levels averaged 5.1 ppm over all three tests and 1.2 ppm over the two PCB tests. A large CO peak occurred during the first day, with measured CO levels as high as 150 ppm. However, CO levels were consistently low during the PCB tests; the highest recorded value was 4.5 ppm. The automatic shutoff system could allow CO concentrations up to 50 ppm. Some CO spikes did occur during these tests. The most notable one resulted from a flame failure in the kiln. However, this spike, as well as the others, lasted for only a very short period of time.

Oxygen and carbon dioxide levels averaged 12.2 percent and 5.9 percent, respectively, over the three tests. An excess oxygen level of 4.5 percent is considered adequate for this facility. The higher values of $CO_2$ generally indicate better combustion efficiency, which is given by the formula:

$$\text{Combustion Efficiency} = CE = 100X\,[CO_2]/([CO_2] + [CO_3]),$$

Where $[CO_2]$ and [CO] are the concentrations of carbon dioxide and carbon monoxide, respectively, as percents.

Combustion efficiencies have been included in the summary tables of Section two (Tables 5 and 6). The overall combustion efficiency for these tests was 99.9912 percent. The lowest combustion efficiency encountered during the two PCB tests was 99.99 percent, which is well above the EPA requirement of 99.9 percent. The lowest combustion efficiency encountered during the first test day was 99.7506 percent, which resulted from the 150 ppm CO peak mentioned previously.

### 4.4.3 Mass Flow Rates Through the Incinerator

In addition to fuel and organic waste, water and large amounts of ambient air were introduced into the incineration system. Table 8 presents a breakdown of mass flow rates for these materials, given as averages for each test day. Ordinary liquid organic waste was fired into both the kiln and the combustion chamber, but only total flow can be calculated since measurements were taken from a common storage tank. Water, natural gas, and fuel oil inputs were read from utility meters. Feed rates for all other wastes including PCB containing materials were calculated from frequent observations of the weight of material being handled on the waste loading dock. Total combustion gas is the sum of the ambient air, water injection, and total fuel inputs.

Ambient air flow was calculated using theoretical combustion equations and ultimate analyses of the various fuels performed by the ENSCO laboratory. These data can be found in Appendix C. The theoretical air requirement of a given fuel (or composite fuel, as is the case here) can be found by knowing that a certain amount of oxygen will react with the carbon in the fuel and whatever hydrogen is in excess of the chlorine content. This amount of oxygen, offset by the amount already contained in the fuel itself, is that required for perfect combustion. Excess air is calculated as follows (3),

$$\text{Excess air} = \text{EA}\ \frac{([O_2] - [CO]/2)}{(.264)(79)-([O_2]-[CO]/2)}$$

where $[O_2]$ and [CO] are concentrations in percent, as measured by the continuous monitors. A relationship can be established between the theoretical air requirement of the fuel and the known excess air after a near perfect combustion process. In this way, the mass flow of ambient air through the combustion can be deduced.

TABLE 8. DAILY AVERAGES OF MASS FLOW RATES THROUGH THE INCINERATOR

| Flow | Test One, 8-26-80 Background Fuel lb/hr | Test One, 8-26-80 Background Fuel kg/hr | Test Two, 8-27-80 PCB & Background Fuel lb/hr | Test Two, 8-27-80 PCB & Background Fuel kg/hr | Test Three, 8-28-80 PCB & Fuel Oil lb/hr | Test Three, 8-28-80 PCB & Fuel Oil kg/hr |
|---|---|---|---|---|---|---|
| Total Fuel | 4948 | 2239 | 4800* | 2172* | 3637* | 1646* |
| Inert Fraction | 228 | 103 | 456 | 206 | 360 | 163 |
| Combustible Fraction | 4720 | 2136 | 4344 | 1966 | 3277 | 1483 |
| Liquid Organic Waste | 3871 | 1752 | 3048 | 1379 | 0 | 0 |
| Capacitors | 198 | 90 | 1213* | 549* | 1128* | 510* |
| Waste Oil | 37 | 17 | 520* | 235* | 459* | 208* |
| Sludge, Ink & Paint | 810 | 367 | 0 | 0 | 0 | 0 |
| Natural Gas | 32 | 14 | 19.3 | 8.7 | 158 | 71 |
| Fuel Oil | 0 | 0 | 0 | 0 | 1892 | 856 |
| Water Injected | 3645 | 1649 | 3140 | 1421 | 4740 | 2145 |
| Ambient Air | 85837$^+$ | 38840$^+$ | 79722$^+$ | 36073$^+$ | 87754$^+$ | 39708$^+$ |
| Combustion Gas | 94430$^+$ | 42729$^+$ | 87662$^+$ | 39666$^+$ | 96131$^+$ | 43498$^+$ |

*Contains PCBs

$^+$Based on combustion equation calculation

From Table 8 it can be seen that total fuel feed rates range from roughly 1584 to 2262 kg/hr (3500 to 5000 lbs/hr). Also, from this table it is obvious which fuels were burned on which days and their relative amounts. The combustible and inert fractions were calculated from the ash content of the composite fuel, known from ultimate analysis to be 4.6, 9.5, and 9.9 percent for the first, second, and third test days, respectively. The total fuel input, added to the flows of water and ambient air, gives a range of average total combustion gas flow rates from 39,666 kg/hr (87,662 lb/hr) to 43.498 kg/hr (96,131 lb/hr).

### 4.4.4 Residence Time

Residence times were calculated by dividing the stated volume of the combustion region by the volumetric flow rate of the combustion gases corrected for temperature (2). Correction for pressure was not made because pressures in the system were negligibly different from atmospheric. Mathematically,

$$\text{Residence time} = RT = \frac{V}{Q} = \frac{V}{m/\rho}$$

where V = volume of the combustion zone ($ft^3$), Q = volumetric flow rate ($ft^3$/sec), m = mass flow rate (lb/sec), and $\rho$ = density (lb/$ft^3$) of the combustion gases, respectively.

At ENSCO, the TOU temperature (Figure 1) is normally maintained above the regulatory minimum temperature. Thus, it is the TOU temperature and the volume up to that point (4624 $ft^3$) that were used in calculating residence times.

Gas density as a function of temperature can be calculated from the following relationship (2):

$$\rho = \frac{\text{Tref}}{(13.1)\text{Tcomb}}$$

where $\rho$ = density in lb/$ft^3$, Tref = 60°F (520°R), the constant 13.1 is the volume ($ft^3$) occupied by 1 lb of air at 60°F and 1 atmosphere pressure, and Tcomb is the TOU temperature. These two expressions can be combined to give the following relationship:

$$RT = \frac{(4624\ ft^3)(520°R)}{(13.1\ ft^3/lb)(m\ lb/sec)(\text{Tcomb}\ °R)}$$

Temperatures in the TOU are given in Tables 3 and 6. Combustion gas flow rates are given in Table 8. Calculated residence times are given in Tables 5 and 6. All residence times are of the order of 2.5 seconds, in excess of the minimum allowed by the PCB Regulations.

### 4.4.5 System Drafts and Pressures

Table 9 presents a summary of most of the important system drafts and pressures for the three test days. These include the draft due to the forced air fan in the grinder enclosure, the pressure differential across the screw worm auger, the kiln draft, the combustion chamber (TOU) draft, the jet draft (measured just upstream from the jet nozzle, the pressure differential across the demister pad, and the stack draft (measured just above the demister pad). Scrubber draft measurements were not taken on a 15 minute basis.

Since the venturi jet provides most of the motive power for this system, the highest draft measurements were expected to occur here. Reference to Table 9 shows that they did. Jet drafts of 7.10, 6.62, and 6.42 inches of water (1.33, 1.24, and 1.20 cm Hg) occurred on the three test days. All of the other draft measurements were under 0.5 inches of water (0.09 cm Hg). Although scrubber draft measurements were not taken every 15 minutes, the following two observations from test three show that the scrubber operates at a slightly lower draft than is present at the jet:

| Time | Jet Draft | Scrubber Draft |
|---|---|---|
| 9:30 | 8.0 "$H_2O$ (1.49 cm Hg) | 7.8 "$H_2O$ (1.46 cm Hg) |
| 10:15 | 6.1 "$H_2O$ (1.14 cm Hg) | 4.8 "$H_2O$ (0.90 cm Hg) |

The demister $\Delta p$ is usually about 0.1 "$H_2O$ (0.02 cm Hg), which is a low pressure drop for a demister pad.

### 4.4.6 Scrubber Operation

Except for scrubber temperatures (Table 7), it was not required to monitor other scrubber operational parameters at 15-minute intervals. Most of the scrubber parameters were fairly constant, except for the caustic usage rate, which varied proportionately with the amount of chlorine in the fuel. Scrubber drafts were somewhat less than the jet draft (the jet draft averaged 6.71 "$H_2O$ or 1.25 cm Hg over the three test days). Scrubber temperature averaged 72°C

## TABLE 9. DAILY SUMMARY OF INCINERATOR DRAFTS AND PRESSURES

| Location of Measurement | | Test One, 8-26-80 Background Fuel $\bar{x}$* | s* | n* | Max | Min | Test Two, 8-27-80 PCB & Background Fuel $\bar{x}$ | s | n | Max | Min | Test Three, 8-28-80 PCB & Fuel Oil $\bar{x}$ | s | n | Max | Min |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Grinder Enclosure | in $H_2O$ | 0.50 | 0 | 4 | 0.50 | 0.50 | 0.09 | 0.0267 | 29 | 0.19 | 0.06 | 0.14 | 0.0529 | 21 | 0.23 | 0.06 |
| | cm Hg | 0.09 | - | - | 0.09 | 0.09 | 0.02 | - | - | 0.04 | 0.01 | 0.03 | - | - | 0.04 | 0.01 |
| ΔP Across Auger | in $H_2O$ | 0.12 | 0.0245 | 4 | 0.15 | 0.10 | 0.13 | 0.0583 | 29 | 0.24 | 0.04 | 0.17 | 0.0793 | 21 | 0.30 | 0 |
| | cm Hg | 0.02 | - | - | 0.03 | 0.02 | 0.02 | - | - | 0.04 | 0.01 | 0.03 | - | - | 0.006 | 0 |
| Kiln Draft | in $H_2O$ | 0.14 | 0.0455 | 4 | 0.20 | 0.10 | 0.18 | 0.0456 | 29 | 0.26 | 0.11 | 0.23 | 0.0495 | 21 | 0.35 | 0.15 |
| | cm Hg | 0.03 | - | - | 0.04 | 0.02 | 0.03 | - | - | 0.05 | 0.02 | 0.04 | - | - | 0.07 | 0.03 |
| TOU Draft | in $H_2O$ | 0.25 | 0.0413 | 30 | 0.30 | 0,18 | 0.27 | 0.0824 | 28 | 0.38 | 0.16 | 0.26 | 0.0736 | 27 | 0.41 | 0.15 |
| | cm Hg | 0.05 | - | - | 1.59 | 1.10 | 0.05 | - | - | 0.07 | 0.03 | 1.20 | - | - | 1.49 | 0.84 |
| ΔP Across Demister | in $H_2O$ | 0.09 | 0.0268 | 5 | 0.12 | 0.06 | - | - | 0 | - | - | 0.09 | 0.0190 | 25 | 0.14 | 0.06 |
| | cm Hg | 0.02 | - | - | 0,02 | 0.01 | | | | | | 0.02 | - | - | 0.03 | 0.01 |
| Stack Draft | in $H_2O$ | 0.33 | 0.0389 | 22 | 0.41 | 0.23 | 0.35 | 0.0279 | 28 | 0.41 | 0.31 | 0.32 | 0.0212 | 2 | 0.33 | 0.30 |
| | cm Hg | 0.06 | - | - | 0.08 | 0.04 | 0.07 | - | - | 0.08 | 0.06 | 0.06 | - | - | 0.06 | 0.06 |

*$\bar{x}$, s, and n are, respectively, the mean, standard deviation, and number of data points.

(112°F) over the three test days, covering a range from 66 to 79°C (151°F to 175°F). This represents a drop of 884°C (1622°F) from the average combustion chamber exit temperature, recycle flowrate to the scrubber tower is unknown, as well as the flowrate of material from the high velocity jet.

The amount of hydrochloric acid in the flue gas can be determined from the amount of chlorine in the fuel. For instance, the chlorine content of the composite fuel for test one was 26.6 percent. Since the total fuel flowrate was 4948 lbs/hr, this corresponds to 1316 lbs/hr of chlorine or 37.6 lb moles of chlorine. Similarly, 37.6 lb moles of hydrochloric acid corresponds to 1353 lbs/hr of hydrochloric acid. Since an equal number of moles of NaOH (caustic) would be required to neutralize this number of moles of HCl, the theoretical caustic requirement would be about 1500 lbs/hr of NaOH. This compares to an actual caustic consumption of 1789 lbs/hr (810 kg/hr) for the first test day. Equivalent information for the three tests is given in Table 10. The actual caustic usage for the second test was 2084 lbs/hr (943 kg/hr) and 821 lbs/hr (372 kg/hr) for the third test day.

## 4.5 QUALITY ASSURANCE

### 4.5.1 Test Preparation

All steps needed to clean the train, as well as all glass sample containers, are listed in Figure 5. All impingers used for organic collection were fired to 450°F, nitric acid washed, distilled water rinsed, acetone rinsed, and hexane rinsed. Prior to initial assembly of the train in the field, all parts were rinsed with hexane. This solvent was discarded. All subsequent field cleanings were with glass-distilled water, acetone, and hexane. Only Burdick and Jackson Distilled-in-Glass, or equivalent, organic solvents were used. Visual inspection for contamination was also performed.

To avoid contaminating the trains as they were assembled or disassembled, as much work as possible was done inside a designated lab area.

SMOKING was prohibited in all but designated areas. Prohibited areas included the stack and other sampling locations. Exposure of resin traps was kept to a minimum. If any equipment was contaminated, it was completely recleaned. All organic solvents were stored in amber glass containers. No grease of any type was used on the train including the impingers. If a seal could not

## TABLE 10. CAUSTIC SOLUTION INPUT DATA

| Description of Data | Test One, 8-26-80<br>Background Fuel | Test Two, 8-27-80<br>PCB & Background Fuel | Test Three, 8-28-80<br>PCB & Fuel Oil |
|---|---|---|---|
| Chlorine Content of Fuel (weight percent) | 26.6 | 29.3 | 9.2 |
| Hydrochloric Acid Produced | | | |
| lbs/hr | 1353 | 1446 | 345 |
| kg/hr | 612 | 654 | 156 |
| Theoretical Caustic Requirement | | | |
| lbs NaOH/hr | 1485 | 1587 | 379 |
| Kg NaOH/hr | 672 | 718 | 172 |
| Actual Consumption | | | |
| lbs NaOH/hr | 1789 | 2084 | 821 |
| Kg NaOH/hr | 810 | 943 | 372 |

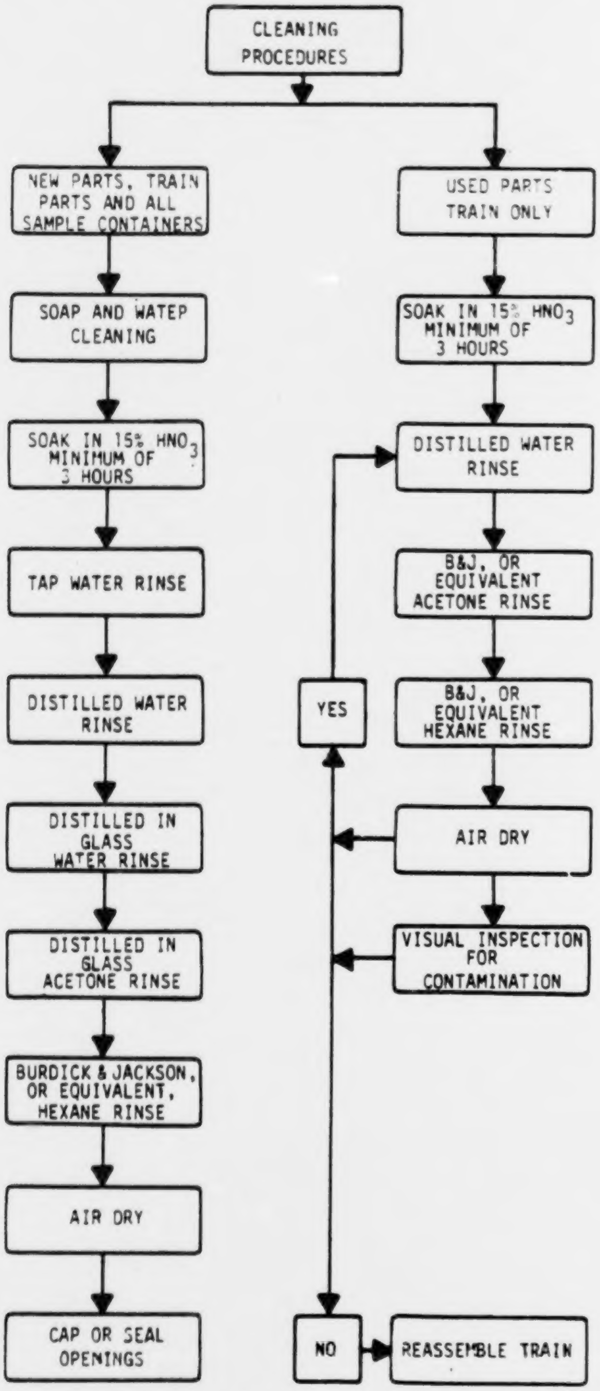
CLEANING PROCEDURES
NEW PARTS, TRAIN PARTS AND ALL SAMPLE CONTAINERS
USED PARTS TRAIN ONLY
SOAP AND WATEP CLEANING
SOAK IN 15% HNO3 MINIMUM OF 3 HOURS
SOAK IN 15% HNO3 MINIMUM OF 3 HOURS
TAP WATER RINSE
DISTILLED WATER RINSE
DISTILLED WATER RINSE
B&J, OR EQUIVALENT ACETONE RINSE
YES
B&J, OR EQUIVALENT HEXANE RINSE
DISTILLED IN GLASS WATER RINSE
AIR DRY
DISTILLED IN GLASS ACETONE RINSE
VISUAL INSPECTION FOR CONTAMINATION
BURDICK & JACKSON, OR EQUIVALENT, HEXANE RINSE
AIR DRY
CAP OR SEAL OPENINGS
NO
REASSEMBLE TRAIN

Figure 5. Cleaning procedures.

be attained, that part was replaced in the sampling train.

The resins used through the PCB test sequences were cleaned by the following methodology,

- 10 gallons of distilled water is rinsed through the resin to remove residual salts.
- A 24 hour continuous reflux of Distilled-In-Glass methanol to remove water.
- For XAD-2, a 24 hour reflux with Distilled-In-Glass methylene chloride to remove organic solvent.
- For Florisil, a 24 hour reflux of a blend of 5% diethyl ether and 95% Hexane to remove organics.
- Both resins were then dried under constant flowing nitrogen until no organic residual odor is noticed.

Upon completion of cleaning a composite sample of each resin type was submitted for a quality control check which consisted of extraction, concentration of extract, and total chromatographable organics (TCO), and gravimetric residues. If the resin did not meet the 1.5 mg/150 g of resin for TCO and 3.8 mg/150 g of resin for residue weight, it was rejected and returned for additional cleaning.

### 4.5.2 Method Five Calibration Data

This section describes the calibration procedures used prior to conducting the field test at ENSCO's incinerator facility. Figure 6 shows the calibration equipment and how it was set up.

#### 4.5.2.1 Orifice Meter Calibration--

The orifice meter calibration is performed using a pump and metering system as illustrated in Figure 6 (a). The dry gas meter with attached critical orifice is run at various orifice flows for a known time. After each run the volume of the dry gas meter, meter inlet/outlet temperatures, time, and orifice setting is recorded. The orifice meter calibration factor is derived by solving the equation.

$$\Delta H@ = \frac{0.317 \quad \Delta H}{Pb\ (T_d + 460)} \quad \left[\frac{(Tw + 460)}{Vw} \quad \theta\right]^2$$

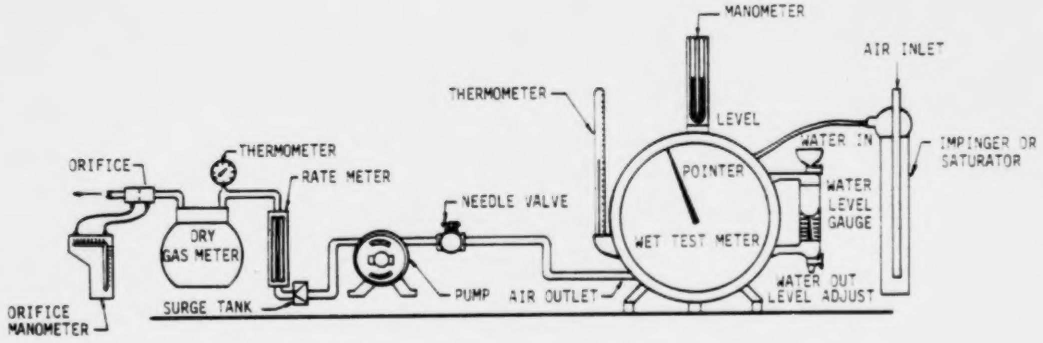

Figure 6a. Orifice and dry gas meter calibration.

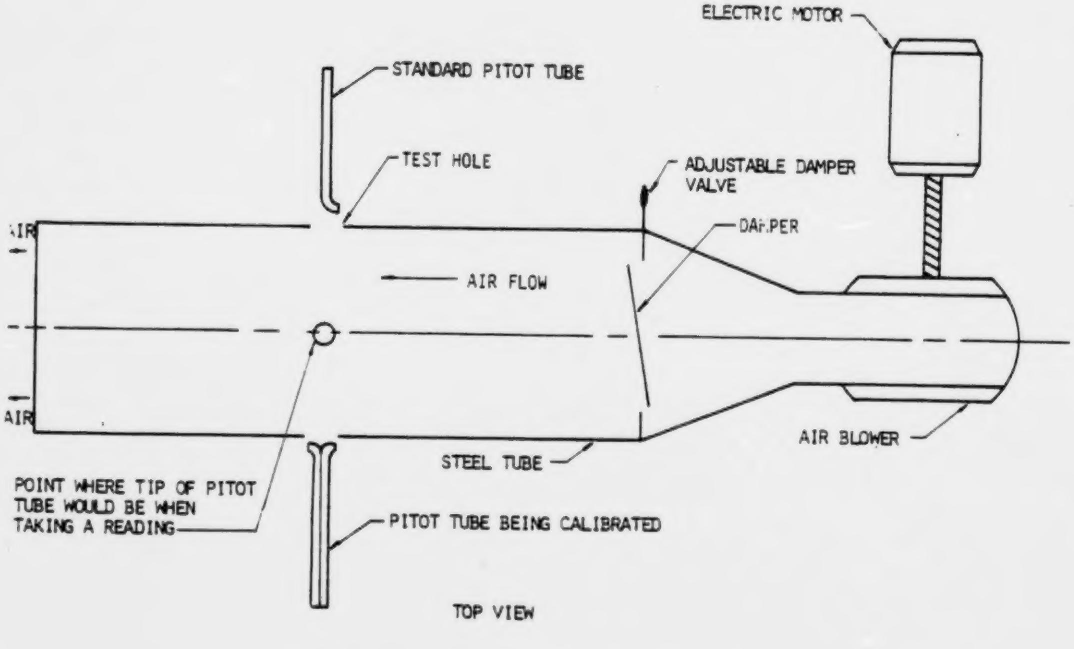

Figure 6b. Pitot tube calibration.

where

$\Delta H$ = Average pressure drop across the orifice meter, inches $H_2O$

Pb = Barometric pressure, inches mercury

$T_d$ = Temperature of the dry gas meter, °F

Tw = Temperature of the wet test meter, °F

$\theta$ = Time, minutes

Vw = Volume of wet test meter, cubic feet

The $\Delta H@$ yielded is utilized to adjust the sampling train flow rate by regulating the orifice flow.

### 4.5.2.2 Dry Gas Meter Calibration--

Meter box calibration consists of checking the dry gas meter for accuracy. The dry gas meter with attached critical orifice is connected to a wet test meter (see Figure 6 (a)) and run at various orifice flows for a known time. After each run wet and dry gas meter volumes, temperatures, time, and orifice readings are recorded. Utilizing the equation:

$$V = \frac{Vw\ Pb\ (Td + 460)}{Vd\ \left(Pb + \frac{\Delta H}{13.6}\right)\ (T_w + 460)}$$

where

V = Volume correction factor (also known as "Y" in EPA Method 5)

Vw = Volume of wet test meter, cubic feet

Pb = Barometric pressure, inches mercury

Td = Temperature dry gas meter, °F

Vd = Volume of dry gas meter, cubic feet

$\Delta H$ = Average pressure drop across the orifice meter, inches $H_2O$

Tw = Temperature of wet test meter, °F

a volume factor which compares the dry gas meter with the wet test meter is obtained.

### 4.5.2.3 Pitot Tube Calibration--

Pitot tubes are calibrated on a routine basis utilizing two methods.

The type S pitot tube specifications are illustrated and outlined in the Federal Register, Standards of Performance for New Stationary Sources, [40 CFR Part 60], Reference Method 2 (refer to Figure 6 (b)). When measurement of pitot openings and alignment verify proper configuration, a coefficient value of 0.84 is assigned to the pitot tube.

If the measurements do not meet the requirements as outlined in the Federal Register, a calibration is then performed by comparing the S type pitot tube with a standard pitot tube (known coefficient of 1.0). Under identical conditions, values of P, for both S type and standard pitot tube are recorded using various velocity flows (14 fps to 60 fps). The pitot tube calibration coefficient is determined utilizing the following equation,

$$\text{Pitot Tube Calibration Factor (CP)} = (\text{Standard Pitot Tube Coefficient}) \times \left[\frac{\Delta P \text{ reading of std. pitot}}{\Delta P \text{ reading of S type pitot}}\right]^{1/2}$$

The coefficient assigned to the pitot tube is the average of calculated values over the various velocity ranges.

### 4.5.2.4 Nozzle Diameters--

The nozzle diameters were calibrated with the use of a vernier caliper. If the nozzle showed excessive wear or was considered not fit for use, it was discarded.

### 4.5.3 Gas Chromatograph Calibration

Manufacturer's recommended calibration procedures were followed using the following standard gas mix which had an accuracy of ± 2%:

| | |
|---|---|
| Carbon Dioxide | 15% |
| Oxygen | 5.15% |
| Carbon Monoxide | 7.23% |
| Nitrogen | Balance |

(All gases contained in one cylinder)

Scott Environmental Technology Inc., Specialty Gas Division

Calibrations were performed at the start of each test day. Replicate injections of the standard gas mixture were made until a comparison of corresponding peak heights were in agreement to within 5%. At this point, the gas chromatograph was considered calibrated and ready for sample analysis. A strip chart recorded was used to record both the calibration and test data.

### 4.5.4 Blanks

For each test conducted at the ENSCO facility, a blank sampling train was set up. The blank train consisted of the back half of the PCB train, impingers, impinger solutions and resin traps. Prior to the start of a specific test, the blank train was transported to the stack where it remained, protected from light, for the duration of the test. Upon completion of the test, the blank was recovered utilizing the same recovery procedure as the test sample.

In addition to the blank train, a small portion of the solvents, approximating the amounts used in rinsing the train, was composited during each test cleanup and submitted as a solvent blank.

### 4.5.5 Chain of Custody

Once the samples were recovered from the sampling trains, liquid and solid streams, they were labeled, taped and shipped according to EPA's chain of custody requirements.

The samples were individually wrapped with bubble-pak or other suitable packaging material, placed in shipping containers and then given to Federal Express or United Parcel Service for shipment to Wright State Laboratory. A chain of custody form accompanied each sample shipment and each sample/shipment was sealed and labeled with EPA chain of custody tags.

See Appendix E for the daily chain of custody record forms.

## 5. TECHNICAL PROBLEMS AND RECOMMENDATIONS

The major problem that occurred during the tests at ENSCO was plugging of the sorbent traps. This problem at ENSCO was less serious than that at Rollins, but plugging did cause delays. A brown to red-brown material was distributed throughout the train but appeared to be concentrated particularly in the glass frit of the XAD-2 sorbent trap. The material could be either organic or inorganic in nature. It should be noted, however, that the material passed through two water filled and ice bath cooled impingers before entering the XAD-2 trap. Perhaps it would be better to use a glass wool plug instead of a glass frit in the sorbent traps in order to avoid plugging problems.

It was recommended that the material be analyzed, so that this problem might be avoided in future test projects. These analyses are underway at Wright State University.

There were also other, minor problems: occasional leaks in the trains and some samples damaged in transit to Wright State University. These problems would have been lessened had the test preparation period been longer than two weeks and had there been a wider choice of shipping companies available. It is also recommended that all samples be shipped in metal ice chests instead of cardboard cartons.

There were minor facility problems: plugged line slurry valve, inadequately shredded capacitors, and jamming of the shredder. These sorts of problems are routine, and there is little than can be done to prevent them from occurring.

# 6. REFERENCES

1. Steiner, J., N.W. Flynn, and C.D. Wolbach. Disposal of Polychlorinated Biphenyls (PCBs) and PCB-Contaminated Materials, Volume 4: Test Incineration of Electrical Capacitors Containing PCBs. Electric Power Research Institute Report No. EPRI FP-1207, September, 1980.
2. Beard, J.H. and J. Schaum. Sampling Methods and Analytical Procedures Manual for PCB Disposal: Interim Report, Report Prepared by U.S. EPA, Office of Solid Waste Management, February 10, 1978.
3. Babcock & Wilcox. Steam, Its Generation and Use. 39th Edition, 1978.

## A. GASEOUS MONITORING

Monitoring of oxygen and carbon dioxide for stack gas molecular weight determination was performed at the ENSCO facility. The sampling positions were located at ports midway on the stack exit after the incineration and scrubber units.

The gas sample was drawn through a stainless steel probe, polypropylene tubing, and an ice bath condenser by means of a small diasphragm pump. A flow rate meter was used to measure sample flow to a Tedlar bag. The collected gas sample was then analyzed for carbon dioxide, oxygen, and nitrogen with a thermal conductivity detector gas chromatrograph. The collection device consisted of the following components.

- Probe - stainless steel with a glass wool plug to act as a filter
- Condenser - air cooled or ice bath to eliminate excess moisture
- Valve - needle valve to regulate sample gas flow rate
- Pump - leak-free, diaphragm type, or equivelent to transport sample gas to the Tedlar bag
- Flow rate meter - meter capable of measuring a flow range from 0 to 1.0 liter per minute
- Gas sample bag - Tedlar sample bag or equivalent, with a capacity of approximately 0.5 - 1.0 cubic foot
- Manometer - water filled U-tube or dry gas meter to be used for the Tedlar bag leak check
- Vacuum gauge - gauge or meter to be used for the sample train leak check.

Prior to field use, all Tedlar gas sample bags were leak checked. The bags were leak checked by inflating them to a pressure of 5 to 10 cm $H_2O$ (2-4 in Hg) as determined by an in-line manometer or equivalent. Any displacement in the manometer after a 10-minute time interval was taken as indicative of a leak. In the field prior to the sampling operation, the sampling train was also leak checked. The leak check was done by placing a vacuum gauge at the probe inlet, pulling a vacuum of at least 250 mm Hg (10 in. Hg), and then turning off the pump. The vacuum should remain stable for at least one minute.

A sample was taken as follows:

- Place the probe in the stack at the sampling point and purge the sample line up to the bag
- Connect the bag and make certain that all connections are tight
- Fill and evacuate bag twice before taking analysis sample
- Sample at a rate that will fill the bag in 10 minutes
- Remove full bag, cap opening, transport to lab, and analyze as soon as possible.

In the lab area, the Tedlar bag was analyzed on the Shimadzu gas chromatograph, model GC-3BT. The resultant peak heights were compared to a known standard gas purchased from Scott Environmental Technology, Inc.

Table A-1 presents the gas analysis data as collected from both the "hot zone" and outlet sampling points at the ENSCO Facility.

TABLE A-1. ENSCO GAS MONITORING DATA

| Date | Time Sampled | Sampling Location | Results | | Comments |
|---|---|---|---|---|---|
| | | | $CO_2$ | $O_2$ | |
| 8/26 | 1320-1327 | Outlet | 7.41 | 11.60 | |
| | 1356-1408 | Hot Zone | 8.16 | 10.30 | Compare with ENSCO $O_2$ Readings |
| | 1435-1449 | Outlet | 6.53 | 12.40 | |
| | 1615-1626 | " | 5.90 | 12.50 | |
| | 1642-1657 | " | 5.65 | 12.70 | |
| | 1720-1730 | " | 6.15 | 12.30 | |
| | 1750-1805 | " | 5.40 | 12.60 | |
| | 1830-1840 | " | 5.40 | 13.10 | |
| | 1905-1915 | " | 6.03 | 12.60 | |
| | 1938-1949 | " | 6.41 | 12.30 | |
| 8/27 | 1247-1305 | Outlet | 6.43 | 13.09 | |
| | 1356-1402 | " | 5.33 | 13.89 | |
| | 1425-1435 | " | 4.97 | 14.16 | |
| | 1500-1510 | " | 6.06 | 13.30 | |
| | 1530-1544 | " | 7.64 | 13.95 | |
| | 1635-1648 | " | 5.58 | 13.73 | |
| | 1712-1722 | Hot Zone | 7.64 | 11.59 | Compare with ENSCO $O_2$ Readings |
| | 1758-1808 | Outlet | 5.94 | 12.98 | |

(Continued)

TABLE A-1. (Continued)

| Date | Time Sampled | Sampling Location | Results $CO_2$ | Results $O_2$ | Comments |
|---|---|---|---|---|---|
| 8/28 | 1132-1147 | Outlet | 5.11 | 13.73 | |
| | 1226-1238 | " | 4.87 | 13.94 | |
| | 1320-1330 | " | 5.23 | 13.78 | |
| | 1412-1427 | " | 6.69 | 12.47 | |
| | 1730-1740 | " | 4.50 | 13.63 | |
| | 1755-1805 | Hot Zone | 6.57 | 11.83 | Compare with ENSCO $O_2$ Readings |

# APPENDIX B

# FIELD DATA SHEETS

The material on pages 47-92 is not suitable for reproduction.

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## C. PROCESS DATA

Appendix C presents raw process monitoring data sheets taken by ENSCO personnel and checked by TRW while the three tests were in progress. The sheets are organized by days, corresponding to the three test days (8-26-80, 8-27-80, and 8-28-80). Each day contains at least five kinds of data sheets. At the end of the appendix is a set of notes from ENSCO's Engineering Manager, listing some fuel feed data and a set of sample calculations for the third test day. These calculations are the same as those used for the other two days.

The five data sheets for each day include the control room sheet (TOU operations), a "Kiln Operations" sheet, a "Liquid PCB Operations" sheet, a "Hammermill Operations" sheet, and a "Forklift Operations" sheet. The TOU operations sheet contains drafts in inches $H_2O$, $O_2$ and $CO_2$ concentrations in percent, CO concentration in ppm, temperatures in °F, gas meter readings in hundreds of cubic feet, and various storage tank levels in inches. The kiln operations sheets contains the kiln temperature in "F, drafts and pressures in inches $H_2O$, and water meter readings in tens of gallons. The Hammermill operations sheet contains the weights in pounds of barrels of solid capacitors, and the time frame in which they were fed to the Hammermill. The liquid PCB sheet contains analogous data for the liquid feed. The forklift operations sheet duplicates information on the Hammermill operations sheet. In addition to these, a maintenance operations sheet is included for the first day, and a record of fuel oil feed is included for the third day.

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# APPENDIX D

# CALIBRATION DATA

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# APPENDIX E

# CHAIN OF CUSTODY RECORDS

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# Division 5

4 17

"DETERMINATION OF POLYCHLORINATED DIBENZO-p-DIOXINS (PCDDs), DIBENZOFURANS (PCDFs), AND BIPHENYLS (PCBs) IN STACK EFFLUENTS AND OTHER SAMPLES FROM PCB INCINERATION TESTS AT ROLLINS ENVIRONMENTAL SERVICES, DEER PARK, TEXAS AND ENERGY SYSTEMS COMPANY (ENSCO), EL DORADO, ARKANSAS"

Interim Report Under
U.S. EPA Cooperative Agreement No. CR806846
Submitted To
Mr. Michael Dellarco, U.S. EPA
Washington, D.C. 20460

# DETERMINATION OF POLYCHLORINATED DIBENZO-p-DIOXINS (PCDDs), DIBENZOFURANS (PCDFs), AND BIPHENYLS (PCBs) IN STACK EFFLUENTS AND OTHER SAMPLES RESULTING FROM ASSESSMENTS OF PCB INCINERATION TESTS AT ROLLINS ENVIRONMENTAL SERVICES, DEER PARK, TEXAS AND ENERGY SYSTEMS COMPANY (ENSCO), EL DORADO, ARKANSAS

INTERIM REPORT ON WORK ACCOMPLISHED UNDER U.S. EPA COOPERATIVE
AGREEMENT NO. CR806846

Prepared By

T.O. Tiernan, J.G. Solch, G.F. VanNess, J. Garrett, M. Porter and M.L. Taylor

BREHM LABORATORY
WRIGHT STATE UNIVERSITY
DAYTON, OHIO 45435

Submitted To

Mr. Michael Dellarco
U.S. Environmental Protection Agency
Office of Pesticides and Toxic Substances
Special Pesticide Review Division
Washington, D.C. 20460

February 15, 1981

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## I. INTRODUCTION

In July, 1980 the U.S. Environmental Protection Agency completed planning for a series of sampling and monitoring activities to be conducted at two commercial incinerators, one operated by Rollins Environmental Service, and located at Deer Park, Texas, and the other operated by Energy Systems Company (ENSCO), and located at El Dorado, Arkansas. These source assessments, sponsored by the EPA's Office of Pesticides and Toxic Substances and managed by EPA's Region VI office in Dallas, Texas, were aimed primarily at determining the concentrations and mass emission rates of chlorinated dibenzo-p-dioxins (CDDs) and chlorinated dibenzofurans (CDFs) in the stack effluents from each incinerator. The sampling and field measurement tasks associated with these tests were conducted under contract with EPA by TRW, Environmental Engineering Division, Redondo Beach, California, while all analyses of collected samples were accomplished by The Brehm Laboratory, Wright State University, Dayton, Ohio, under EPA Cooperative Agreement No. CR806846. The present interim report describes a portion of the analytical results obtained by Wright State in the course of this project.

# II. DESCRIPTION OF INCINERATION TESTS AND SAMPLING PROCEDURES UTILIZED BY TRW

## A. Incinerator Systems at Rollins Environmental Services and Energy Systems Company (ENSCO).

The incineration facilities at the Rollins and Ensco plants have been described in some detail in the plan for testing developed by TRW,[1] and will be only briefly mentioned here, in order to provide a basis for discussion of the various types of samples which were collected during the monitoring tests.

The incineration system utilized by Rollins Environmental Services consists of a rotary kiln and a liquid injection burner, both feeding a common afterburner. Temperatures attainable in these three burners are normally 1300-1500°C. The overall retention time of the incineration system is 2-3 seconds. Solid wastes can be fed into the rotary kiln by conveyor, (although no solids were burned during the tests described here), while liquids and sludges are pumped into the kiln or into the liquid injection burner. Auxiliary fuel, natural gas, is used for initial heat-up and to provide supplemental heat for the incineration of low heat capacity wastes. Fuel oil (Number 2) is also used to provide heat for burning materials such as PCBs, and is mixed with the PCBs prior to the waste being fed into the incinerator. Gaseous emissions from the combustion of solid and liquid wastes are controlled by a Venturi scrubber. Lime is injected to neutralize the scrubber water, which is then admitted to settling ponds, where the

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water is analyzed and subjected to further treatment, if necessary, prior to discharge into the Houston-ship channel. Exhaust gases are also routed through absorption traps and a mist eliminator before entering the 30-meter exhaust stack.

The incineration system utilized by Energy Systems Company (ENSCO) is also capable of combusting both solid and liquid wastes. This incinerator consists of a rotary kiln, in which combustion temperatures of 1200-1500°F are attained, and in which the retention time for solid material is approximately one hour and the gas retention time is approximately 4 seconds. Liquid wastes, water and natural gas can also be injected into the front end of the kiln. Ash is removed from the end of the kiln by a drag chain and placed in steel drums for storage. Gases which are evolved from the rotary kiln pass into an afterburner which consists of two separate combustion chambers. Residence time in the primary chamber is approximately 2.2 seconds and temperatures of 2250-2340°F are typically maintained there. Most of the organic waste materials are destroyed in this region. Molten slag resulting from the combustion settles on the chamber floor and is removed through a slag trap. The secondary combustion chamber is baffled to facilitate gas mixing, and the residence time in this chamber is approximately 2 seconds, while the temperature is typically 1400°F. The total residence time for gases in both chambers is about 4.5 seconds. The scrubber at the ENSCO facility is also of the Venturi jet type. Gases evolved from the combustion chamber are quenched with lime and caustic solution as they enter the bottom of the scrubber. This treatment removes particulates and neutralizes acidic gases such as HCl. Spent scrubber liquor is transferred to a holding tank which then overflows to a sludge lagoon. Spent scrubber solution is available for recycling. After neutralization, the combustion gases pass through the Venturi section of the scrubber, in which recycled scrubber water is sprayed to facilitate particulate removal. Ultimately, sludge and liquids from the lagoon are discarded by deep-well injection.

## B. Incineration Tests Conducted at Rollins and ENSCO.

Sampling and monitoring were accomplished by TRW during three different modes of operation at each of the incinerators tested. The materials combusted and the conditions for each of these tests are as follows:

1. Test 1. For Test 1, each incinerator was operated under the conditions at which incineration is normally conducted. Temperatures in this case were not necessarily maintained at 1200°C as required for PCB incineration. At the Rollins plant, the materials combusted were liquid chlorinated hydrocarbon wastes, such as vinyl chloride still bottoms. At the ENSCO plant, shredded capacitors (solids, but not containing PCBs) were incinerated, along with chlorinated hydrocarbon wastes, such as pesticide process wastes, as well as paint and ink manufacturing wastes.

2. Test 2. For Test 2, the materials combusted at the Rollins incinerator, consisted of the same types of materials as described for Test 1, along with liquid PCB wastes. Similarly, at ENSCO, the Test 2 incinerator

feed included the normally processed wastes (as in Test 1) along with both liquid PCBs and shredded PCB-containing capacitors. Combustion temperatures for Test 2 were maintained near 1200°C at both plants, as required by EPA regulations for incineration of PCBs.

3. Test 3. For Test 3, the materials combusted at Rollins consisted of a mixture of liquid PCB wastes and clean fuel oil. At the ENSCO plant, the materials incinerated during Test 3 included both liquid PCB wastes and PCB-containing capacitors, mixed with diesel fuel. Again, temperatures were maintained at the levels required for PCB incineration.

## C. Sampling Procedures and Types of Samples Collected.

The sampling procedures and apparatus utilized in the monitoring tests at the Rollins and ENSCO incinerators have been described in detail in documentation prepared by TRW,[1] and only those aspects which relate to the samples ultimately analyzed by Wright State will be briefly summarized here.

1. Stack Effluent Samples. Stack effluents were collected by using a modified EPA Method 5 sampling train, which consisted of a glass probe (capable of being heated to 250°F), followed by a series of three glass impingers (the first containing 100 ml. of distilled water, the second containing 200 ml. of distilled water, and the third being empty), a sorbent trap containing XAD-2 resin, a sorbent trap containing Florisil, and a fourth impinger containing silica gel. The train was backed by appropriate gauges, valves, meters, and a pump, for the purpose of controlling and

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monitoring flow through the train. No filter was inserted between the probe and impingers, so any particulates collected entered the impingers and were immersed in the liquids. The impingers were cooled by immersing them in an ice bath for the purpose of condensing moisture from the stack effluent stream. The sorbent traps were also cooled by circulating chilled water through the exterior jackets. The sorbent traps incorporated a glass fritted disc on one end, which retained and supported the sorbent bed, and the sorbent was held in place by a glass wool plug at the other end of the trap. The traps, as well as the probe and the impingers, were interconnected using standard glass ball and socket joints, which were not greased for these tests. All components of the sample train were rigorously cleaned, using standard procedures, prior to use.

Upon termination of a stack sampling event, the probe was removed from the stack and the train was dissassembled. The nozzle and glass probe were rinsed with approximately 100 ml. of acetone and 100 ml. of hexane, and the interior surfaces were scrubbed with a nylon brush. The rinses and any materials removed from the probe were transferred to a pre-rinsed amber glass bottle and the bottle was sealed with a teflon-lined cap. The contents of the first three impingers were pooled by pouring the liquids into a single amber glass bottle. The interior chamber of each impinger was rinsed successively with 30 ml. of acetone and 30 ml. of hexane and these rinse solutions were placed in the same bottle containing the collected impinger liquids. Rinsings of connector tubing were also placed in this container, which again, was sealed with a teflon-lined lid. The XAD-2 and Florisil sorbent tubes were removed and sealed by placing mating ground glass caps on the end joints of each tube. Appropriate solvent and water blank samples were also collected during the tests and placed in sealed amber glass bottles. Several method blank samples were also obtained by charging and assembling a complete train, then dissassembling the train components (unused) and collecting the appropriate samples.

From the foregoing, it is seen that five types of samples requiring analyses for PCDDs, PCDFs and PCBs result from the stack sampling. These types of samples are:

- Probe Wash
- Impinger catch and rinses (composite)
- XAD-2 resin traps
- Florisil traps
- Solvent and method blanks

2. Solids and Liquid Samples. Concurrent with the stack sampling, samples of appropriate solids and liquids relevant to the incineration process (feed materials, combustion products, emission control equipment samples) were also collected by simple grab sampling. Such samples were collected at appropriate intervals during the incineration tests,[1] and were placed in prerinsed amber glass bottles and sealed with teflon-lined caps. These samples are listed below.

a. Rollins. Only liquid process stream samples were collected at the Rollins facility. These included:

- Liquid PCB and waste feed.
- Well-water feed
- Lime slurry feed
- Touch-up tank
- Effluent discharge

b. ENSCO. Both solid and liquid process stream samples were collected at the ENSCO facility. These included:

- Shredded capacitors
- Kiln ash
- Liquid PCB feed
- Liquid waste feed
- Well water
- Scrubber liquor
- Recycled scrubber liquor
- Caustic solution
- Lime slurry

## D. Shipment of Samples to Wright State.

Sampling activities at the Rollins and ENSCO facilities were initiated by TRW in early August, 1980, and shipment of samples to Wright State University for analyses began on August 5, 1980. Wright State continued to receive shipments through September 17, 1980. A complete listing of all samples received in the nine separate shipments, including dates of arrival at Wright State, and information on sample condition, was provided in writing to Mr. Michael Dellarco, EPA Dioxin Monitoring Program Coordinator, on September 26, 1980. Photographs of some of the samples and resin traps were taken by Wright State and these were also provided to Mr. Michael Dellarco in a communication on December 15, 1980. As discussed in these communications, while most of the samples shipped to Wright State were received in good condition, several of the sample bottles containing liquids leaked, several other sample vessels were broken resulting in loss of the sample, and a few samples were lost entirely in the course of shipment and did not arrive at Wright State. In some of the shipments during which breakage occurred during transit, the shipper had been forced to repackage some of the sample vessels since the original shipping box was disintegrated or destroyed. In the latter cases, chain of custody records were lost and sample integrity could not be ensured. In spite of these problems, since duplicate sets of train samples were collected in all of the tests (dual trains were utilized), an essentially complete set of samples in reasonably good condition was available from each test for analysis.

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## III. ANALYTICAL METHODOLOGY

### A. Sample Handling and Preparation.

As noted already, some of the liquid samples from the sampling trains (probe rinses and impinger samples) contained two distinct layers, and in one case suspended solid material was visible. After allowing such samples to stand for a period sufficient to effect complete separation of the layers, each layer of these samples was removed to a separate amber glass sample container fitted with a teflon-lined lid, so that each phase could be analyzed separately. The quantities of the liquid phases varied considerably from sample to sample, and in a few instances, only one layer was present. It is not known whether these variations are due entirely to leakage of the sample containers (which did occur in many samples) or to variations in the sampling train operation and rinsing procedures followed by TRW. In the one sample where particulate could be seen, the particulate was removed separately by filtration. In subsequent attempts to remove and and extract this particulate, the latter was lost owing to the extremely small quantity available and the small particle size. The separated liquid layers were subsequently processed as described below and analyzed.

The XAD-2 resin and the Florisil traps were removed from the sampling trains by TRW, the ends were sealed with glass caps, and the traps were shipped intact to the Brehm Laboratory. Prior to analysis of a given trap at the Brehm Laboratory, the XAD-2 resin or Florisil was removed and transferred to a clean amber glass vessel fitted with a teflon-lined cap. Aliquots of the sample were subsequently removed for processing as described below. The

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total sample was manually mixed prior to taking an aliquot, in an effort to ensure homogeneity and representative sampling. In all cases, both the XAD-2 resin and Florisil appeared to contain substantial quantities of water (although the quantity varied from sample to sample) and the solid sorbents were agglomerated and difficult to remove from the traps. In fact, some quantities of the sorbents adhered tenaciously to the inner surfaces of the traps and could not be removed. The quantities remaining could not be determined and related to the original weight of resin because the weights of the individual traps prior to packing, and the weight of the water absorbed by the solid sorbent in each trap could not be reliably determined. Consequently, there is an uncertainty in the reported analytical results arising from the fact that these data do not take into account the residues of the sorbents left in the traps. The quantities of these residues were generally small however. No attempt was made to dry the XAD-2 or Florisil samples prior to analysis, since it was thought that this might also lead to loss of volatile chemical compounds trapped on these sorbents. The total weight of the sorbent removed from the trap was determined prior to analysis. Aliquots of the sorbents taken for analysis were also weighed, of course, and by relating these aliquots to the total quantity of sorbent removed, the total burden within the trap of the compounds analyzed could be determined.

Another factor which bears on the accuracy of the reported data for the XAD-2 resin and Florisil traps should also be mentioned here. It was observed that the glass frits of the traps received by the Brehm Laboratory had been perforated, so that they exhibited large non-uniform holes of varying sizes. Apparently, according to information received from TRW, holes were punched during the actual sampling tests because the glass frits plugged and the desired flow rate through the sampling train could not otherwise have been achieved. These observations raise questions about the uniformity of exposure of the solid sorbents to the gas stream during the sampling process. The colorations observed in various parts of the traps also raise similar questions. Several of the traps from the tests at the ENSCO plant exhibited a pronounced red-brown coloration on the frit and on the glass wool plugs at the other end of the solid sorbent bed, but the sorbent itself appeared to have retained its characteristic stark white color. This was observed for both the XAD-2 resin and the Florisil traps. Similarly, many of the Rollins traps exhibited a bright yellow color on the frits and the glass wool plugs at the other end of the sorbent bed, but the sorbents themselves appeared to be stark white with no indication of the yellow color. In the case of traps originating from Test 3, at the ENSCO site, the frit was covered with an oily residue (gray in color) but again the resin appeared to be "clean". Again, these observations suggest that the sorbents may not have been uniformly exposed to the sampled stack gas stream. If this is true, the analytical data obtained for the sorbent traps represent, at best, lower limits in terms of the concentrations of CDDs, CDFs and PCBs which were present in the stack effluents.

Photographs of the sorbent traps from these tests which document the observations mentioned above, were provided earlier to EPA by the Brehm Laboratory in our communication of Dec. 15, 1980.

As noted above, small quantities of the solid sorbents could not be removed from the traps. Also, the colored contaminants just mentioned which appeared on the glass frits of the traps as well as other solid deposits on the trap walls remained in the traps after the bulk of the sorbents had been removed. Since it is important to know whether or not these trap residues may include CDDs, CDFs, or PCBs, attempts were made to extract these residues from one trap by immersing the entire trap (after the sorbent had been removed) in a very large Soxhlet apparatus and employing the extraction procedures described below. The extract was subsequently analyzed to determine content of the compounds of interest.

Other solid samples (feed materials, etc.) were analyzed as received. Aliquots of these were removed from the sample vessels in which the samples were received, and weighed. Again, attempts were made to ensure that a reasonably representative sample was selected but with the course solid feed materials (for example, shredded capacitors) and the viscous scrubber samples there is no certainty that this was achieved.

## B. Analytical Methods Development and Testing.

At the outset of this program, analytical methods to accomplish quantitative measurements of the CDDS, CDFs and PCBs in samples of the type collected in this assessment had not been demonstrated. In fact, a complete survey of combustion effluents for all classes of CDDs and CDFs had not been reported by any workers in this country. In previously reported studies,[2] Wright State had obtained quantitative data on CDDs, including some information on isomeric composition of the TCDDs, for effluents from a municipal refuse incinerator. Dow Chemical scientists had also reported the results of comprehensive studies of CDDs in various combustion products.[3,4] The samples

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collected in the Rollins/ENSCO tests however, encompass a much broader array of sample types than have previously been examined in such surveys. Accordingly, it was necessary to develop and test the efficacy of analytical procedures which could be applied for the required analyses.

The approach taken for developing the needed analytical procedures by our laboratory entailed initial application of methodology similar to that which we have applied previously for combustion products and other hazardous waste samples containing CDDs. In order to gauge the efficacy of these procedures portions of samples were spiked with labelled $^{37}Cl_4$-2,3,7,8-TCDD, and other labelled CDDs, and the samples were then analyzed to determine the recovery of these CDDs. If recoveries were not acceptable (usually a minimum recovery of 50% of the added labelled internal standard was used as a criterion of acceptability) then the extraction and/or cleanup procedures were modified and another spiked sample aliquot was analyzed using the modified methods. This procedure was repeated until recovery of the added CDD was acceptable. It was not possible to accomplish the same type of tests for the CDFs because no labelled CDF was available or could be obtained for used as an internal standard in the studies reported here. A limited number of experiments were conducted with CDFs using the method of standard additions, in which a given sample was analyzed before and after addition of a known quantity of an unlabelled CDF standard. The methods ultimately developed and validated for the determinations reported here are described in the following sections.

The extent to which information on the CDD and CDF isomers present in the samples could be obtained was limited by the availability of pure standards of the isomers which could be used for comparisons of GC retention times and mass spectral response. Of the total 75 CDD and 132 CDF isomers which are possible only 33 CDDs and 10 CDFs are available in our laboratory. A listing of these is given in Tables 1 and 2. In addition, it is seen that four other isotopically labelled CDDs are on hand.

## C. Extraction of Samples and Preliminary Separation of CDDs, CDFs and PCBs From Other Matrix Constituents.

The procedures developed and applied for extraction of the samples and preliminary separation of the compounds of interest are as follows.

### 1. Extraction.

a. Liquid samples. Measure the total volume of the liquid sample. Transfer approximately one-half of the total sample (or up to 40 ml) to a precleaned 125 ml amber glass bottle. Add appropriate quantities of the internal standards, $^{37}Cl_4$-2,3,7,8-TCDD and $^{37}Cl_4$-1,2,3,4,6,7,8-HpCDD. Add 40 ml of petroleum ether, seal the vessel tightly with a teflon-lined cap, and agitate the vessel vigorously on a laboratory shaker for a period of one hour. Proceed with step 2.

b. Solid samples. Accurately weigh an aliquot of the XAD-2 or Florisil sorbent (or other solid sample) corresponding to approximately one-half of the total sample (typically 5-13 g), place this in a precleaned glass thimble, and add appropriate quantities of the internal

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standards, $^{37}Cl_4$-2,3,7,8-TCDD and $^{37}Cl_4$-1,2,3,4,6,7,8-HpCDD, directly to the sample in the thimble. Insert the thimble into a precleaned Soxhlet apparatus, charge the Soxhlet reservoir with 100 ml of benzene, and apply heat to the reservoir to extract the sample. Continue extraction for a period of 16 hours. Remove the extract and concentrate to a volume of about 5 ml using a Snyder column. Transfer the concentrate to a precleaned 125 ml glass bottle and add 40 ml of petroleum ether. Proceed with step 2.

2. Clean-up and liquid chromatographic separation.

a. Add 50 ml of doubly distilled water to the vessel containing the sample extract, reseal the vessel and agitate for 10 minutes. Allow the vessel to stand for a period sufficient for the aqueous and organic layers to separate completely, and remove and discard the aqueous layer.

b. Using the same procedure as applied in 2a., wash the extract successively with 50 ml portions of 20% KOH, doubly distilled water, concentrated $H_2SO_4$ (except in this case agitate mixture for 15 min.), and doubly distilled water, in each case discarding the washing agent. The acid washing procedure is repeated until the acid layer is visually colorless.

c. Add 5 g of anhydrous sodium sulfate to the washed extract and allow to stand in order to remove residual water. Transfer the extract to a centrifuge tube and concentrate to near dryness by placing the tube in a water bath at 55°C, and passing a gentle stream of filtered, prepurified $N_2$ over the solution.

d. Prepare a glass macro-column, 20 mm OD x 230 mm in length, tapered to 6 mm OD on one end. Pack the column with a plug of silanized glass wool, followed successively by 1.0 g silica, 2.0 g silica containing 33% (w/w) 1M NaOH, 1.0 g silica, 4.0 g silica containing 44% (w/w) concentrated $H_2SO_4$ and 2.0 g silica. Quantitatively transfer the concentrated extract from Step c. to the column and elute with 45 ml hexane. Collect the entire eluent and concentrate to a volume of 1-2 ml in a centrifuge tube, as before.

e. Construct a disposable liquid chromatography mini-column by cutting off a Pyrex 10 ml disposable pipette at the 2.0 ml mark and packing the lower portion of the tube with a small plug of silanized glass wool, followed by one gram of Woelm basic alumina, which has been previously activated for at least 16 hours at 600°C in a muffle furnace, and cooled in a dessicator for 30 minutes just prior to use. Quantitatively transfer the concentrate from Step d. onto the liquid chromatography column, rinse the centrifuge tube consecutively with two 0.3 ml portions of 3% $CH_2Cl_2$ -in-hexane, and also transfer the rinses to the chromatography column.

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f. Elute the column with 10 ml of 3% (v/v) $CH_2Cl_2$-in-hexane and retain the eluent for PCB analysis.

g. Elute the column with 10 ml of 50% (v/v) $CH_2Cl_2$-in-hexane and retain the eluent for analyses for CDDs and CDFs.

h. Elute the column with 5 ml $CH_2Cl_2$ and retain the eluent to check for retention of CDDs and CDFs on the column.

i. Concentrate each of the retained fractions to a volume of approximately 1 ml by heating the tubes in a water bath while passing a stream of prepurified $N_2$ over the solutions, as described above. Quantitatively transfer the concentrated fractions into separate 2 ml micro-reaction vessels, splitting each fraction so that one-half goes into each of two sample vessels. (The contents of one vessel are analyzed for CDFs, and the contents of the other for CDDs). Evaporate the solutions in each of the micro-reaction vessels almost to dryness, using the procedures just mentioned, rinse the walls of each vessel down with 0.5 ml $CH_2Cl_2$, and reconcentrate just to dryness.

j. Approximately 1 hour before gas chromatographic-mass spectrometric (GC-MS) analysis, dilute the residue in each micro-reaction vessel with an appropriate quantity of benzene (depending upon the anticipated quantities of analytes in each vessel) and gently swirl the solvent in the vessel to ensure dissolution of CDDs, CDFs and PCBs.

k. If preliminary GC-MS screening analysis of the sample indicates the presence of potential interfering compounds (that is, which obscure the CDD, CDF or PCB signals) or other sample matrix constituents which elute from the GC at very long times, then additional sample clean-up or fractionation is required using high performance liquid chromatography (HPLC). The HPLC used for this purpose is described below. The sample is injected into the HPLC and appropriate fractions are collected, as determined in advance, by injecting pure CDD and CDF standards and measuring the retention times of these.

## D. Analysis of Sample Extracts Using Gas Chromatography-Mass Spectrometry (GC-MS).

Two separate gas chromatographic-mass spectrometric methods of analysis were employed in this program, one utilizing low resolution gas chromatography-high resolution mass spectrometry (LRGC-HRMS), and the other utilizing high resolution gas chromatography-low resolution mass spectrometry (HRGC-LRMS). For determination of total TCDDs in the extracts of the samples LRGC-HRMS employed. This technique yields essentially unequivocal quantitative data on the total TCDDs present in the analyte, (assuming that the instrument response is the same for all TCDD isomers) but does not yield information regarding the quantities of specific TCDD isomers which are present. For these analyses, a modified MS-30 mass spectrometer, operated in selected-ion monitoring mode, is used. This technique utilizes a specialized step-scan circuit and associated electronic hardware developed by our laboratory. Both m/z 319.8966 and 321.8936 are monitored as indicators of TCDD during the period when TCDDs elute from the gas chromatograph and thus, quantitation of the TCDDs detected can be based upon the signal observed at either mass. The theoretical ratio of m/z 320:m/z 322 resulting from TCDD (based on the known isotopic abundances of $^{35}$Cl and $^{37}$Cl and the numbers of Cl substituents in the molecular ion) is 0.77, and the experimentally observed ratio should be essentially the same as the theoretical ratio. This is another criterion which the data should satisfy in order to certify with confidence that TCDD is indeed detected. Since the ion signal at m/z 327.8846, which arises from the $^{37}$Cl$_4$-2,3,7,8-TCDD internal standard added to all samples prior to processing, is also monitored concurrently with the two masses typical of native TCDDs, and the quantitation of native TCDDs is actually based upon the ratios of the signals at m/z 320 and m/z 322 to that at m/z 328, the TCDD data obtained are inherently "recovery corrected". This is, of course, one of the chief reasons for utilizing an internal standard, and results in improved accuracy. The percent recovery of the internal standard is specified in the data listings solely for the purpose of illustrating the overall efficiency of the analytical procedure.

For determining the total concentrations of each of the various other classes (pentachlorinated through octachlorinated) of chlorinated dibenzo-p-dioxins and dibenzofurans in the sample extracts, a sophisticated HRGC-LRMS technique was employed. A complex computer-controlled selected ion monitoring scheme was utilized for this purpose and the compounds in each extract were quantitated during two separate GC-MS runs. The ions monitored during these

GC-MS analyses for each group of CDDs and CDFs are listed in Table 3, while the sequence of GC and MS operations are shown in Tables 4 and 5 for the two runs. These procedures permit the monitoring of ion masses characteristic of each class of CDDs and CDFs during the appropriate gas chromatographic retention time interval. As expected, the monochlorinated CDDs and monochlorinated CDFs have similar retention times. However, use of a 50 M (WCOT) fused silica gas chromatographic column provides optimum separation and minimizes overlap of individual compounds. As mentioned earlier, of the 75 possible CDDs and 135 possible CDFs, authentic standards of only a limited number are available in our laboratory for use in calibration (see Tables 1 and 2). Therefore, most of the CDD and CDF peaks observed in the analyses of the sample extracts cannot be assigned to a specific isomer. Thus, in arriving at a quantitative value for a given class of CDDs or CDFs, the areas of the mass chromatographic peaks appearing at the appropriate retention times, and having the appropriate mass spectral response, were summed and compared to the corresponding area observed from injection of a known quantity of a calibration standard of the same class. In general, a single CDD or CDF isomer of each chlorinated group (i.e., monochlorinated, dichlorinated, etc.) was used in the calibration process. However, since all 22 TCDD isomers are available in our lab, it is possible to make a reasonably definitive identification of most of the TCDD isomers present in the samples, because the techniques employed permit complete separation of many of these isomers.

Sample extracts expected to contain PCBs were also subjected to HRGC-LRMS analysis, using selected ion monitoring. PCB standards representative of several classes of PCBs (monchlorinated through decachlorinated) were used to calibrate the GC-MS and to determine appropriate GC retention time parameters and sensitivities for each PCB class. The mass spectral ions indicative of each PCB class which were monitored at the appropriate retention time are shown in Table 6. The same monitoring sequence was applied to the sample extracts in order to estimate the quantities of total PCBs of each class which were present.

Specific details of the apparatus, operating conditions and experimental parameters for the GC-MS analyses reported herein are given in the following.

### 1. Parameters For Low Resolution Gas Chromatographic-High Resolution Mass Spectrometric (LRGC-HRMS) Analysis of Sample Extracts.

a. Instrumentation: Varian 3740 Gas Chromatograph coupled through an AEI silicon membrane separator to a modified AEI MS-30 Mass Spectrometer. Modifications to the MS-30 include a new ESA power supply and incorporation of a custom built, step-scan circuit which is driven by a Nicolet 1074 Signal Averaging Computer. Four masses are rapidly scanned at the retention time of the dioxin or furan of interst.

#### b. Conditions for the Gas Chromatograph:

Column: 1.8m x 2mm I.D. glass column packed with 1.5% OV-101 on Gas Chrom Q (100/120 mesh)
Carrier Gas: Helium at a flow rate of 30 ml/min
Temperature: Injector: 250°C
Column: 220°C
Transfer Lines: 285°C

#### c. Conditions for the Mass Spectrometer:

Ionizing Voltage: 70 eV
Static Resolution: 1:12, 500 (10% Valley)

Source Envelope Pressure: $5 \times 10^{-5}$ torr

Analyzer Pressure: $5 \times 10^{-6}$ torr

Source Temperature: 250°C

Membrane Separator Temperatures: 215°C

Transfer Line Temperature: 270°C

Ions Monitored: m/z 319.8966, 321.8936, 325.8805, 327.8846

## 2. Parameters For High Resolution Gas Chromatographic-Low Resolution Mass Spectrometric (HRGC-LRMS) Analysis of Sample Extracts.

a. Instrumentation: Perkin Elmer Sigma III Gas Chromatograph Coupled through a custom-fabricated interface including a single-stage glass jet separator to a Kratos MS-25 Mass Spectrometer equipped with a DS-50SM Data System.

b. Conditions For the Gas Chromatograph:

Column: 50M WCOT (OV-101) Silica Capillary

Carrier Gas: Hydrogen, 30 lb head pressure

Column Temp.: Programmed from 190°C to 220°C @ 5°C/min, hold at 220°C for 20 min.

Interface Temp: 250°C

Injector: Split ratio 50:1

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### c. Conditions for the Mass Spectrometer

Selected Ion Monitoring Mode (for m/z's monitored and details of instrumental procedures see Tables 1-3)

Ionizing Voltage: 70 eV

Accelerating Voltage: 4 KV

## E. High Performance Liquid Chromatography (HPLC).

The apparatus and instrumental parameters applied for HPLC fractionation of sample extracts are specified below.

### 1. Parameters For High Performance Liquid Chromatographic (HPLC) Fractionation Of Sample Extracts.

a. Instrumentation: Varian Model 5021 Microprocessor Controlled High Performance Chromatograph equipped with CDS-111L Data System

b. Parameters:

Pressure: Minimum: 10 atm
Maximum: 250 atm
Injection Loop: 25 μl
Column: Guard: 37μ Vydac SC Reverse Phase
4.0 cm x 0.4 cm I.D.
Analytical: 2-Dupont Zorbax-ODS
25.0 cm x 0.6 cm I.D.

Temperature: Guard Column: Ambient
Analytical Column: 50°C

Detector: Fixed UV: 254 nm, 0.01 A.U.F.S.
Variachrom UV-Vis: TCDD, 235 nm, 0.01 A.U.F.S.
HxCDD, HpCDD, 245 nm, 0.01 A.U.F.S.

Program:

| Time | Code | Value |
|---|---|---|
| .0 | % | 100 Methanol |
| .0 | Flow | 2.5 ml/min |
| .0 | Event | Hold |
| .1 | Event | Inject |
| 20.0 | Event | Reset |

## F. Reagents and Chemicals.

The following reagents and chemicals were utilized in the procedures outlined above. Potassium hydroxide, anhydrous sodium sulfate, and sulfuric acid were all Reagent Grade and were obtained from J.T. Baker Chemical Co. or Fisher Scientific Co., Fairlawn, N.J. Methanol, hexane, methylene chloride and benzene were "Distilled in Glass" quality obtained from Burdick and Jackson, Muskegon, Michigan. Petroleum ether (low boiling) was Omnisolve Quality from Matheson, Coleman, and Bell, Cincinnati, Ohio. Woelm basic alumina (Activity Grade I) was obtained from ICN Pharmaceuticals, Cleveland, Ohio. Doubly distilled water was obtained using the all-glass distillation apparatus in the Brehm Laboratory. Prepurified nitrogen was obtained from Airco, Inc. Montvale, New Jersey.

Standards employed in this work were obtained from the sources listed below.

1-chlorodibenzo-p-dioxin-Analabs, Inc., North Haven, Conneticut

2-chlorodibenzo-p-dioxin-Analabs, Inc., North Haven, Conneticut

2,7-dichlorodibenzo-p-dioxin-Analabs, Inc., North Haven, Conneticut

2,3-dichlorodibenzo-p-dioxin-Analabs, Inc., North Haven, Conneticut

1,2,4-trichlorodibenzo-p-dioxin-Analabs, Inc., North Haven, Conneticut

1,2,3,4-tetrachlorodibenzo-p-dioxin-Analabs, Inc., North Haven, Conneticut

$^{37}Cl_4$-2,3,7,8-TCDD-KOR Isotopes, Cambridge, Mass.

2,3,7,8-TCDD and other TCDD isomers-Dow Chemical Co., Midland, Michigan, and H.R. Buser, Swiss Federal Research Station, Wadenswil, Switzerland.

1,2,3,7,8-PCDD-KOR Isotopes, Cambridge, Mass.

1,2,3,4,7,8-HxCDD - Dr. A. Poland, Univ. Rochester, N.Y.

1,2,4,6,7,9-HxCDD-Dr. A. Poland, Univ. Rochester, N.Y.

1,2,3,4,6,7,8-HpCDD-KOR Isotopes, Cambridge, Mass.

OCDD-Analabs, Inc. North Haven, Conneticut

$^{37}Cl_8$-OCDD-KOR Isotopes, Cambridge, Mass.

2,4-dichlorodibenzofuran - All CDFs obtained from U.S. FDA, Wash., D.C.

2,8-dichlorodibenzofuran

1,2,4-trichlorodibenzofuran

1,2,4,8-tetrachlorodibenzofuran

2,3,7,8-tetrachlorodibenzofuran

2,3,6,8-tetrachlorodibenzofuran

1,2,4,7,8-pentachlorodibenzofuran

1,2,4,6,7,9-hexachlorodibenzofuran
1,2,3,4,6,8,9-heptachlorodibenzofuran
Octachlorodibenzofuran

### G. Quality Assurance.

As is the case for all analytical programs conducted at our laboratory, all analytical measurements were accomplished in accordance with good laboratory practice. An extensive quality assurance program is established and followed for all projects such as those described herein. This program includes the analyses of solvent and method blanks, analyses of internally spiked control samples, determinations to validate the efficacy of the analytical procedures applied, as already described. Quality Control for the individual analyses reported here was also provided on a continuing basis for CDD determinations because of the incorporation of known quantities of labelled TCDD and HpCDD internal standards into each sample prior to analysis.

## IV. RESULTS

### A. Total TCDDs and TCDFs

Results obtained from the determinations of total TCDDs and TCDFs in the stack effluents (that is, the individual sampling train samples) from the tests at ENSCO are reported in Tables 7 and 8, respectively. Corresponding data for the tests at Rollins are reported in Tables 9 and 10. The data for total TCDDs and TCDFs are reported separately because these results were considered by EPA to have the greatest relevance for the estimation of health risks in connection with the incineration tests, and were the first results obtained by the Brehm Laboratory in this study. As mentioned earlier, the total TCDD results were obtained by LRGC-HRMS, while the total TCDF data were obtained by HRGC-LRMS.

As noted in the previous section of this report, the results obtained for total TCDDs do not permit any definitive conclusions with respect to the composition of TCDD positional isomers. Such information was obtained however, for both TCDDs and TCDFs from the high resolution (capillary-column) GC-LRMS measurements. These results are discussed below. The data for total TCDDs shown in Tables 7 and 8 indicate that these compounds were detected in the samples from Tests 1 and 2, but not in Test 3 samples, at both Rollins and ENSCO. One possible conclusion which can be drawn from these observations is that the "normal" chlorocarbon wastes incinerated by these plants are the source of the TCDDs (since these were burned in both Tests 1 and 2), whereas incineration of the PCBs (which were the only chlorocarbons burned in Test 3) does not yield TCDDs. There is no obvious rationale for the curious pattern of the TCDD results (for example, the observation of TCDDs in the impinger, probe wash, and XAD-2 resin samples from one test, whereas only the probe wash sample or the impinger sample contained TCDDs in other tests). Possibly, this reflects erratic sampling procedures (as discussed earlier) or variations in the washing of the train components by TRW. Alternatively, temperature fluctuations in various sections of the train might account for some of these observations. Similar peculiarities are apparent in the pattern observed for the total TCDF data (Tables 9 and 10).

Data for both the TCDDs and TCDFs are reported as total quantities present in each type of sample analyzed. Since the volumes and weights of the various samples varied considerably, and since these could not be related to original volumes and weights (these were not provided to us, and in any case, leakage and/or loss of unknown quantities of most samples occurred during shipment) it was not possible to calculate concentrations of TCDDs and TCDFs present in the samples from the analytical data determined by our laboratory. Also, the quantities of TCDDs and TCDFs determined could not be related to the volume of air sampled, since this information was unknown to us.

## B. Isomeric Composition of TCDDs and TCDFs

Data bearing on the isomeric composition of the TCDDs and TCDFs present in representative Rollins and ENSCO samples were also obtained in the present study from the HRGC-LRMS measurements. The latter utilize a 50-meter capillary GC column which is capable of resolving many of the tetrachlorinated isomers. For example, Figure 1 shows selected-ion mass chromatograms obtained for a mixture of 12 TCDD isomers by monitoring sequentially nominal m/z 257 and 259 (the sum of these is displayed); nominal m/z 320 and 322 (sum of these is displayed); and nominal m/z 328 in one GC-MS run. Corresponding displays obtained from the HRGC-LRMS analyses of TRW sample number 6-0606 (Rollins Test 2, Train 1 Probe Wash sample) and sample number 6-0560 (ENSCO Test 2, Train 1 Impinger sample) are shown in Figures 2 and 3 (the numbering of peaks corresponds to that shown in Figure 1). By comparing the observed sequence of peaks in these runs with that observed for the standard isomer mixture (Figure 1), and by utilizing related GC data reported by Buser and Rappe[5] it is possible to positively identify four of the TCDD isomer peaks detected in the analyses of these two samples. It is known from the results cited above that each of these four isomers is completely resolved from the other 21 TCDD isomers, and so identification of these isomers is unequivocal using the experimental conditions employed here. These isomers and their relative quantities (percents of the total TCDDs) are listed in Table 11 for the two samples indicated. Several of the other isomer peaks shown in Figures 2 and 3 also correspond in retention time to specific isomers included in our 12-isomer mixture, but other data obtained both in our lab and elsewhere[5] indicates that these isomers are not uniquely resolved from the other TCDD isomers, and so the identifications of these other peaks (indicated in Table 11) are tentative. Under the presently utilized experimental conditions, the 2,3,7,8-TCDD isomer is also resolved from all other TCDD isomers, and it is therefore possible to state that, within the limits of detection applicable here (50 ppt) 2,3,7,8-TCDD is not detected in the effluent samples analyzed. It seems probable that the isomeric composition of the TCDDs in the other effluent samples would be essentially the same as those detected for the two samples just discussed.

Less definitive data bearing on the isomeric composition of the TCDFs could be obtained because only two TCDF isomer standards were available for calibration purposes (1,2,4,8-TCDF and 2,3,7,8-TCDF). Thus, while a TCDF peak is observed at the retention time corresponding to that of 2,3,7,8-TCDF in the mass chromatograms of many of the samples, completely unequivocal assignment of this peak is not possible. The quantities of the TCDF component which is "apparently" 2,3,7,8-TCDF are listed in Tables 9 and 10, along with the data for total TCDFs. Again, it must be emphasized that this assignment is tentative.

## C. Total Higher Chlorinated CDDs and CDFs

Using the complex sequence of HRGC-LRMS procedures described in an earlier section, the complete series of higher chlorinated CDDs and CDFs (total penta- through octachlorinated) were determined in representative Rollins and ENSCO samples. Typical mass chromatograms obtained in the course of these complete GC-MS scans resulting from two injections of a mixture of such CDD and CDF standards are shown in Figures 4 through 13 The CDD and CDF isomers used in obtaining this calibration data were 1-chlorodibenzo-p-dioxin; 2,7-dichlorodibenzo-p-dioxin; 1,2,4-trichlorodibenzo-p-dioxin; 2,3,7,8-tetrachlorodibenzo-p-dioxin; $^{37}Cl_4$-2,3,7,8-tetrachlorodibenzo-p-dioxin; 1,2,3,4,7,8-hexachlorodibenzo-p-dioxin; 1,2,3,4,6,7,8-heptachlorodibenzo-p-dioxin; octachlorodibenzo-p-dioxin; 2,4-dichlorodibenzofuran; 1,2,4-trichlorodibenzofuran; 2,3,7,8-tetrachlorodibenzofuran; 1,2,4,8-tetrachlorodibenzofuran; 1,2,4,7,8-pentachlorodibenzofuran; 1,2,4,6,7,9-hexachlorodibenzofuran; and octachlorodibenzofuran. Corresponding mass chromatograms resulting from the full GC-MS scan of two injections of the Rollins Test 2, Train 1 Probe wash sample (TRW Number 6-0606) for all classes of CDDs and CDFs are shown in Figures 14 through 22. The quantities of CDDs and CDFs in the Test 1, Train 1 Probe wash sample from Rollins (TRW Number 6-0502) and in the Test 2, Train 1 Impinger sample from ENSCO (TRW Number 6-0560), as determined from similar HRGC-LRMS data are listed in Tables 12 and 13, respectively. It appears that the quantities of CDFs in these samples generally exceed the quantities of the corresponding CDDs. The significance of these observations and their bearing on the combustion mechanisms is not currently apparent, and is difficult to determine in the absence of data on other chemical constituents in the effluents and feed materials.

## D. PCBs

In the limited time which was permitted for the analyses of samples collected in this survey, it was possible to analyze only a single sample for content of PCBs. The sample analyzed was a Florisil trap sample from Rollins Test 2, Train 1 (TRW Number 6-0609), and the results are shown in Table 14. The mass chromatograms obtained for a mixture of PCB standards and for this sample in the course of these analyses are shown in Figures 23 through 28. Clearly, several classes of PCBs were detected in the sample (the estimated quantities are given in Table 14). In the absence of information on the volumes of stack gas sampled in this particular test, we are unable to relate this data to actual effluent concentrations.

## V. SUMMARY

The analytical data obtained by our laboratory which are presented in this report, when related to sampling data provided by TRW, should permit EPA to make preliminary determinations of the mass emission rates of toxic effluents (CDDs and CDFs) from the incineration tests monitored at Rollins Environmental Services and ENSCO. These data in turn should be applicable for accomplishing health-risk assessments for the population exposed to the effluents from these plants. Characterization by the Brehm Laboratory of still other samples resulting from these tests, particularly feed materials and control equipment samples, is still in progress, and such data will hopefully provide much useful information relevant to the mechanisms of formation of toxic compounds such as the CDDs and CDFs in combustion environments.

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## TABLE 1

## LIST OF CHLORODIOXIN ISOMER STANDARDS CURRENTLY AVAILABLE AT THE BREHM LABORATORY-WRIGHT STATE UNIVERSITY

1-Chlorodibenzo-p-dioxin

2-Chlorodibenzo-p-dioxin

2,7-Dichlorodibenzo-p-dioxin

2,3-Dichlorodibenzo-p-dioxin

1,2,4-Trichlorodibenzo-p-dioxin

Tetrachlorodibenzo-p-dioxins - all 22 isomers

$^{37}Cl_4$-2,3,7,8-Tetrachlorodibenzo-p-dioxin

$^{13}C_4$-2,3,7,8-Tetrachlorodibenzo-p-dioxin

$^{14}C_4$-2,3,7,8-Tetrachlorodibenzo-p-dioxin

1,2,3,7,8-Pentachlorodibenzo-p-dioxin

1,2,4,6,7,9-Hexachlorodibenzo-p-dioxin

1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin

1,2,3,4,6,7-Hexachlorodibenzo-p-dioxin

1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin

$^{37}Cl_4$-1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin

Octachlorodibenzo-p-dioxin

$^{37}Cl_8$-Octachlorodibenzo-p-dioxin

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## TABLE 2

## LIST OF CHLORINATED DIBENZOFURAN STANDARDS CURRENTLY AVAILABLE AT THE BREHM LABORATORY-WRIGHT STATE UNIVERSITY

2,4-Dichlorodibenzofuran

3,6-Dichlorodibenzofuran

2,8-Dichlorodibenzofuran

1,2,4-Trichlorodibenzofuran

1,2,4,8-Tetrachlorodibenzofuran

2,3,7,8-Tetrachlorodibenzofuran

1,2,4,7,8-Pentachlorodibenzofuran

1,2,4,6,7,9-Hexachlorodibenzofuran

1,2,3,4,6,8,9-Heptachlorodibenzofuran

Octachlorodibenzofuran

## TABLE 3

## LIST OF ION MASSES MONITORED USING GC-SELECTED-ION MONITORING MASS SPECTROMETRY FOR SIMULTANEOUS DETERMINATION OF MONO-, DI-, TRI-, TETRA-, PENTA-, HEXA-, HEPTA-, and OCTA-CHLORINATED DIBENZO-p-DIOXINS AND DIBENZOFURANS

| Class of Chlorinated Dibenzodioxin or Dibenzofuran | Number of Chlorine Substituents (X) | Monitored m/z for Dibenzofurans $C_{12}H_{8-x}OCl_x$ | Monitored m/z for Dibenzo-p-dioxins $C_{12}H_{8-x}O_2Cl_x$ | Approximate Theoretical Ratio Expected on Basis of Isotopic Abundance |
|---|---|---|---|---|
| Mono- | 1 | 202.019 [a] | 218.013 [a] | 1.00 |
| | | 204.016 | 220.011 | 0.35 |
| Di- | 2 | 235.980 [a] | 251.974 [a] | 1.00 |
| | | 237.977 | 253.972 | 0.69 |
| Tri- | 3 | 269.941 [a] | 285.940 [a] | 0.99 |
| | | 271.938 | 287.937 | 1.00 |
| Tetra- | 4 | 303.902 [a] | 319.897 [a] | 0.74 |
| | | 305.899 | 321.894 | 1.00 |
| | | | 327.885 [b] | -- |
| | | | [256.933] [c] | 0.21 |
| | | | [258.930] [c] | 0.20 |
| Penta- | 5 | 337.863 [a] | 353.858 [a] | 0.57 |
| | | 339.860 | 355.855 | 1.00 |
| Hexa- | 6 | 373.821 | 389.816 | 1.00 |
| | | 375.818 | 391.813 | 0.87 |
| Hepta- | 7 | 407.782 | 423.777 | 1.00 |
| | | 409.779 | 425.774 | 1.00 |
| | | | 431.765 [b] | -- |
| Octa- | 8 | 441.743 | 457.738 | 0.86 |
| | | 443.740 | 459.735 | 1.00 |

[a] Molecular ion peak.

[b] $^{37}Cl_4$-labelled HpCDD standard peak.

[c] Ions which can be monitored in TCDD analyses for confirmation purposes.

# TABLE 4

## SEQUENCE OF OPERATIONS IN GC-MS (MS-25) ANALYSES OF CHLORODIBENZODIOXINS AND CHLORODIBENZOFURANS IN FIRST INJECTION OF SAMPLE EXTRACT

| Elapsed Time (Min) | Event | GC Column Temperature | Temperature Program Rate ( °C/MIN) | Ions Monitored By Mass Spectrometer (m/z) | Compounds Monitored |
|---|---|---|---|---|---|
| 0.00 | Injection, splitless | 190°C | -- | -- | -- |
| 1.50 | Turn on split valve | 190°C | -- | -- | -- |
| 2.00 | Begin Temp. program to 220°C | 190°C | 5°C/min | -- | -- |
| 4.50 | Open column flow to Mass Spec. | 202°C | 5°C/min | -- | -- |
| 5.00 | Start PROGRAM #1 | | | | |
| | Sweep = 100 ppm | | | | |
| | Time on each mass = 0.15 sec | 205°C | 5°C/min | 202.019 | Mono-Cl furans |
| | | | | 204.016 | Mono-Cl furans |
| | | | | 218.013 | Mono-Cl dioxins |
| | | | | 220.011 | Mono-Cl dioxins |
| 8.00 | Column reaches isothermal hold | 220°C | -- | -- | -- |
| 8.75 | Stop PROGRAM #1 | 220°C | -- | -- | -- |
| 9.50 | Start PROGRAM #3 | | | | |
| | Sweep = 100 ppm | | | | |
| | Time on each mass = 0.15 sec | 220°C | -- | 269.941 | $Cl_3$ furans |
| | | | | 271.938 | $Cl_3$ furans |
| | | | | 285.940 | $Cl_3$ dioxins |
| | | | | 289.937 | $Cl_3$ dioxins |
| 16.00 | Stop PROGRAM #3 | | | | |
| 16.75 | Start PROGRAM #5 | 220°C | -- | 327.885 | $^{37}Cl$ labelled TCDD |
| | Sweep = 125 ppm | | | 337.863 | $Cl_5$ furans |
| | Time on penta mass = 0.2 sec | | | 339.860 | $Cl_5$ furans |
| | Time on $^{37}Cl$-TCDD = 0.07 sec | | | 353.858 | $Cl_5$ dioxins |
| | | | | 355.855 | $Cl_5$ dioxins |
| 25.00 | Begin temp program to 235°C | 220°C | 5°C/sec | -- | -- |
| 28.00 | Stop PROGRAM #5 | 235°C | | -- | -- |

## TABLE 4 (cont)

| Elapsed Time (Min) | Event | GC Column Temperature | Temperature Program Rate (Δ°C/Min) | Ions Monitored By Mass Spectrometer (m/z) | Compounds Monitored |
|---|---|---|---|---|---|
| 45.00 | Start PROGRAM #7 | | | | |
| | Sweep = 175 ppm | | | | |
| | Time on each mass = 0.35 sec | 235°C | -- | 407.782 | $Cl_7$ furans |
| | | | | 409.779 | $Cl_7$ furans |
| | | | | 423.777 | $Cl_7$ dioxins |
| | | | | 425.774 | $Cl_7$ dioxins |
| | | | | 431.765 | $^{37}Cl$ labelled HpCDD |
| 60.00 | Stop PROGRAM #7 | | -- | -- | -- |
| 95.00 | Return GC to initial temp | | -- | -- | -- |

## TABLE 5

## SEQUENCE OF OPERATIONS IN GC-MS (MS-25) ANALYSES OF CHLORODIBENZODIOXINS AND CHLORODIBENZOFURANS IN SECOND INJECTION OF SAMPLE EXTRACT

| Elapsed Time (Min) | Event | GC Column Temperature | Temperature Program Rate ( °C/Min) | Ions Monitored By Mass Spectrometer (m/z) | Compunds Monitored |
|---|---|---|---|---|---|
| 0.00 | Injection, splitless | 190°C | -- | -- | -- |
| 1.50 | Turn on split valve | 190°C | -- | -- | -- |
| 2.00 | Begin temp program to 220°C | 190°C | -- | -- | -- |
| 4.50 | Open flow to Mass Spec. | 202°C | 5°C/min | | |
| 6.00 | Start PROGRAM #2 | 210°C | 5°C/min | 235.980 | $Cl_2$ furans |
| | Sweep = 100 ppm | | | 237.977 | $Cl_2$ furans |
| | Time on each mass = 0.15 sec | | | 251.974 | $Cl_2$ dioxins |
| | | | | 253.972 | $Cl_2$ dioxins |
| 8.00 | Column reaches 220°C hold isothermal | 220°C | -- | -- | -- |
| 12.00 | Stop PROGRAM #2 | 220°C | -- | -- | -- |
| 12.75 | Start PROGRAM #4 | 220°C | -- | 303.902 | $Cl_4$ furans |
| | Sweep - 100 ppm | | | 305.899 | $Cl_4$ furans |
| | Time on Cl mass = 0.15 sec | | | 319.897 | $Cl_4$ dioxins |
| | Time on Cl-TCDD =0.05 sec | | | 321.894 | $Cl_4$ dioxins |
| | | | | 327.885 | $^{37}$Cl labelled TCDD |
| 24.00 | Stop PROGRAM #4 | 220°C | -- | -- | -- |
| 25.00 | Begin temp program to 235°C | 220°C | 5°C/min | -- | -- |
| 26.00 | Start PROGRAM #6 | 225°C | 5°C/min | 373.821 | $Cl_6$ furans |
| | Sweep = 150 ppm | | | 375.818 | $Cl_6$ furans |
| | Time on each mass =0.25 sec | | | 389.816 | $Cl_6$ dioxins |
| | | | | 391.813 | $Cl_6$ dioxins |
| 45.00 | Stop PROGRAM #6 | 235°C | -- | -- | -- |
| 46.00 | Start PROGRAM #7 | 235°C | -- | 407.782 | $Cl_7$ furans |
| | Sweep = 175 ppm | | | 409.779 | $Cl_7$ furans |
| | Time on each mass =0.035 sec | | | 423.777 | $Cl_7$ dioxins |
| | | | | 425.774 | $Cl_7$ dioxins |
| | | | | 431.765 | $^{37}$Cl labelled HpCDD |
| 60.00 | Stop PROGRAM #7 | 235°C | -- | 441.743 | $Cl_8$ furans |
| 70.00 | Start PROGRAM #8 | 235°C | -- | 443.740 | $Cl_8$ furans |
| | Sweep = 225 ppm | | | 457.738 | $Cl_8$ dioxins |
| | Time on each mass = 0.55 sec | | | 459.735 | $Cl_8$ dioxins |
| 90.00 | Stop PROGRAM #8 | | | | |
| 95.00 | Return to initial temp | 235°C | -- | | |

## TABLE 6

## LIST OF ION MASSES MONITORED USING GC-SELECTED-ION MONITORING MASS SPECTROMETRY FOR SIMULTANEOUS DETERMINATION OF MONO- THROUGH DECA- CHLORINATED POLYCHLORINATED BIPHENYLS (PCBs)

| Class of Chlorinated PCB | Number of Chlorine Substituents | Ions Monitored (m/z) For PCB[$C_{12}H_{10-x}Cl_x$] |
|---|---|---|
| Mono- | 1 | 188.039<br>190.036 |
| Di- | 2 | 222.000<br>223.997 |
| Tri- | 3 | 255.961<br>257.958 |
| Tetra- | 4 | 289.922<br>291.919 |
| Penta- | 5 | 325.880<br>327.877 |
| Hexa- | 6 | 359.841<br>361.839 |
| Hepta- | 7 | 393.802<br>396.800 |
| Octa- | 8 | 427.763<br>429.761 |
| Nona- | 9 | 463.722<br>465.719 |
| Deca- | 10 | 497.683<br>499.680 |

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## TABLE 7

## WRIGHT STATE UNIVERSITY-BREHM LABORATORY
## DAYTON, OHIO 45435
## RESULTS OF ANALYSES OF STACK EFFLUENT SAMPLES FROM INCINERATOR LOCATED AT ENSCO, EL DORADO, ARKANSAS, FOR TETRACHLORODIBENZO-p-DIOXINS (TCDDs)
## (PCB DESTRUCTION TESTS)

| TEST AND SAMPLE TRAIN NUMBERS | TRW SAMPLE NUMBER | SAMPLE TYPE | NATIVE TCDDs DETECTED IN ENTIRE SAMPLE m/z 320 | m/z 322 | Average | MINIMUM DETECTABLE QUANTITY | % RECOVERY [a.] |
|---|---|---|---|---|---|---|---|
| TEST 1, TRAIN 2 [b.] | 6-0528 | Probe wash | 0.167<br>0.167 ng | 0.149 ng | 0.158 ng | .057<br>0.062 ng. | 146% |
| TEST 1, TRAIN 2 | 6-0529 | XAD-2 resin | 0.088 ng | 0.122 ng | 0.105 ng | 0.062 ng | 104% |
| TEST 1, TRAIN 2 | 6-0530 | XAD-2 resin | 0 | 0 | 0 | 0.073 ng | 85% |
| TEST 1, TRAIN 2 | 6-0531 | Florisil | 0 | 0 | 0 | .060<br>0.062 ng | 128% |
| TEST 2, TRAIN 1 | 6-0560 | Impinger [c.] | 0.400 ng | 0.551 ng | 0.476 ng | 0.22 ng | 45% 41 |
| TEST 2, TRAIN 1 | 6-0561 | Probe wash | 0 | 0 | 0 | 0.25 ng | 99% |
| TEST 2, TRAIN 1 | 6-0562 | XAD-2 resin | 0 | 0 | 0 | 0.38 ng | 134% |
| TEST 2, TRAIN 1 | 6-0563 | Florisil | 0 | 0 | 0 | 0.66 ng | 57% |
| TEST 3, TRAIN 1 | 6-0574A | Impinger [c.] | 0 | 0 | 0 | 0.35 ng | 71% |
| TEST 3, TRAIN 1 | 6-0574B | Probe wash | 0 | 0 | 0 | 0.21 ng | 98% |
| TEST 3, TRAIN 1 | 6-0574C | XAD-2 resin [d.] | 0 | 0 | 0 | 0.20 ng | 94% |
| TEST 3, TRAIN 1 | 6-0574D | Florisil (1 of 2) | 0 | 0 | 0 | 0.20 ng | 122% |
| TEST 3, TRAIN 1 | 6-0574E | Florisil (2 of 2) | 0 | 0 | 0 | 0.45 ng | 46% |

## TABLE 7 (cont)

[a] Based on $^{37}Cl_4$-2,3,7,8-TCDD added as internal standard.

[b] Impinger sample from this series was broken when received by Wright State.

[c] Upper layer (apparently hexane fraction) only.

[d] The other XAD-2 resin trap was not received by Wright State.

TABLE 8

WRIGHT STATE UNIVERSITY-BREHM LABORATORY
DAYTON, OHIO 45435
RESULTS OF ANALYSES OF STACK EFFLUENT SAMPLES FROM
INCINERATOR LOCATED AT ROLLINS ENVIRONMENTAL SERVICES, INC., DEER PARK,
TEXAS, FOR TETRACHLORODIBENZO-p-DIOXINS (TCDDs)
(PCB DESTRUCTION TESTS)

| TEST AND SAMPLE TRAIN NUMBER | TRW SAMPLE NUMBER | SAMPLE TYPE | NATIVE TCDDs DETECTED IN ENTIRE SAMPLE | | | MINIMUM DETECTABLE QUANTITY | % RECOVERY [a.] |
|---|---|---|---|---|---|---|---|
| | | | m/z 320 | m/z 322 | Average | | |
| TEST 1, TRAIN 1 | 6-0581 | Impinger [b.] | 1.61 ng | 1.97 ng | 1.79 ng | 0.43 ng | 100% |
| TEST 1, TRAIN 1 | 6-0582 | Probe wash | 3.16 ng | 4.51 ng | 3.84 ng | 0.43 ng | 100% |
| TEST 1, TRAIN 1 | 6-0583 | XAD-2 resin | 0.53 ng | 2.09 ng[c.] | 1.31 ng | 0.43 ng | 100% |
| TEST 1, TRAIN 1 | 6-0584/<br>6-0585<br>(composite) | Florisil | 0 | 0 | 0 | 0.70 ng | 44% |
| TEST 2, TRAIN 1 | 6-0605 | Impinger [b.] | 0 | 0 | 0 | 0.27 ng | 75% |
| TEST 2, TRAIN 1 | 6-0606 | Probe wash | 1.32 ng | 1.52 ng | 1.42 ng | 0.27 ng | 129% |
| TEST 2, TRAIN 1 | 6-0607/<br>6-0608<br>(composite) | XAD-2 resin | 0 | 0 | 0 | 0.38 ng | 107% |
| TEST 2, TRAIN 1 | 6-0609 | Florisil | 0 | 0 | 0 | 0.48 ng | 79% |
| TEST 3, TRAIN 2 | 6-0643 | Impinger [d.] | 0 | 0 | 0 | 0.90 ng | 100% |
| TEST 3, TRAIN 2 | 6-0644 | Probe wash [d.] | -- | -- | -- | -- | -- |
| TEST 3, TRAIN 2 | 6-0645 | XAD-2 resin | 0 | 0 | 0 | 0.30 ng | 80% |
| TEST 3, TRAIN 2 | 6-0646 | Florisil | 0 | 0 | 0 | 0.35 ng | 58% |

[a] Based on $^{37}Cl_4$-2,3,7,8-TCDD added as internal standard.

[b] Upper layer (apparently hexane fraction) only.

[c] Incompletely resolved interference at m/z 322 results in elevated signal.

[d] Sample contained only one layer which appeared to be the acetone-water layer; upper hexane layer observed in other samples was completely absent.

# TABLE 9

## WRIGHT STATE UNIVERSITY-BREHM LABORATORY
## DAYTON, OHIO 45435
## RESULTS OF ANALYSES OF STACK EFFLUENT SAMPLES FROM INCINERATOR LOCATED AT ENSCO, EL DORADO, ARKANSAS, FOR TETRACHLORODIBENZOFURANS (TCDFs)
## (PCB INCINERATION TESTS)

| TEST AND SAMPLE TRAIN NUMBERS | TRW SAMPLE NUMBER | SAMPLE TYPE | QUANTITY OF TOTAL TCDFs IN ENTIRE SAMPLE [a.] | APPARENT NUMBER OF TCDF ISOMERS [b.] | QUANTITY OF APPARENT 2,3,7,8-TCDF [c.] | MINIMUM DETECTABLE QUANTITY OF TCDF | % RECOVERY [d.] |
|---|---|---|---|---|---|---|---|
| TEST 1, TRAIN 2 [e.] | 6-0528 | Probe wash | 0 | 0 | 0 | 1 ng. | 50% |
| TEST 1, TRAIN 2 | 6-0529 | XAD-2 resin | 0 | 0 | 0 | 2 ng. | -- [h.] |
| TEST 1, TRAIN 2 | 6-0530 | XAD-2 resin | 0 | 0 | 0 | 0.1 ng. | 70% |
| TEST 1, TRAIN 2 | 6-0531 | Florisil | 2.0 ng. | 4 | 0.5 ng. | 0.4 ng. | 100% 30 |
| TEST 2, TRAIN 1 | 6-0560 | Impinger [f.] | 4.0 ng. | 3 | 1.0 ng. | 0.5 ng. | 45% 100 |
| TEST 2, TRAIN 1 | 6-0561 | Probe Wash | 0.5 ng. | 2 | 0.2 ng. | 0.09 ng. | 75% |
| TEST 2, TRAIN 1 | 6-0562 | XAD-2 resin | 1.5 ng. | 5 | 0.3 ng. | 0.05 ng. | 100+% |
| TEST 2, TRAIN 1 | 6-0563 | Florisil | 0 | 0 | 0 | 0.08 ng. | 100% |
| TEST 3, TRAIN 1 | 6-0574A | Impinger [f.] | 0 | 0 | 0 | 0.5 ng. | 100+% |
| TEST 3, TRAIN 1 | 6-0574B | Probe wash | 0 | 0 | 0 | 0.2 ng. | 100+% |
| TEST 3, TRAIN 1 | 6-0574C | XAD-2 resin [g.] | 0 | 0 | 0 | 0.08 ng. | 100% |
| TEST 3, TRAIN 1 | 6-0574D | Florisil (1 of 2) | 0 | 0 | 0 | 0.4 ng. | 51% 15 |
| TEST 3, TRAIN 1 | 6-0574E | Florisil (2 of 2) | 0 | 0 | 0 | 0.09 ng. | 85% 82 |

TABLE 9 (cont)

[a] Based on summation of the areas of all mass chromatographic peaks observed in a selected TCDF retention time window, while monitoring m/z 304 and 306; it is assumed that the instrument response determined by calibrating with an authentic 2,3,7,8-TCDF standard is the same for all TCDF isomers.

[b] The number of discrete mass chromatographic peaks observed in the TCDF window. Since all TCDF isomers are not available for determination of GC retention times, it is not known whether or not each peak represents more than one isomer. The number cited is therefore the minimum number of TCDF isomers which can be present in the sample.

[c] Determined on the basis of the mass chromatographic peak which has a retention time corresponding to that of the 2,3,7,8-TCDF isomer. Other TCDF isomers may also be included in this peak.

[d] Based on $^{37}Cl_4$-2,3,7,8-TCDD added as an internal standard.

[e] Impinger sample from this series was broken when received by Wright State.

[f] Upper layer (apparently hexane fraction) only.

[g] The other XAD-2 resin trap was not received by Wright State.

[h] Recovery could not be determined on basis of low resolution MS analysis because of unresolved interference at m/z 328.

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TABLE 10

**WRIGHT STATE UNIVERSITY-BREHM LABORATORY**
**DAYTON, OHIO 45435**
**RESULTS OF ANALYSES OF STACK EFFLUENT SAMPLES FROM INCINERATOR LOCATED AT ROLLINS ENVIRONMENTAL SERVICES, INC., DEER PARK, TEXAS, FOR TETRACHLORIDIBENZOFURANS (TCDFs)**
**(PCB DESTRUCTION TESTS)**

| TEST AND SAMPLE TRAIN NUMBERS | TRW SAMPLE NUMBER | SAMPLE TYPE | QUANTITY OF TOTAL TCDFs IN ENTIRE SAMPLE [a.] | APPARENT NUMBER OF TCDF ISOMERS [b.] | QUANTITY OF APPARENT 2,3,7,8-TCDF [c.] | MINIMUM DETECTABLE QUANTITY OF TCDF | % RECOVERY [d.] |
|---|---|---|---|---|---|---|---|
| TEST 1, TRAIN 1 | 6-0581 | Impinger [e.] | 3.5 ng. | 6 | 0.7 ng. | 0.08 ng. | 100+% |
| TEST 1, TRAIN 1 | 6-0582 | Probe wash | 5.0 ng. | 7 | 0.5 ng. | 0.15 ng. | 100% |
| TEST 1, TRAIN 1 | 6-0583 | XAD-2 resin | 5.0 ng. | 8 | 0.3 ng. | 0.15 ng. | 100% |
| TEST 1, TRAIN 1 | 60584/<br>6-0585<br>(composite) | Florisil | 0 | 0 | 0 | 0.08 ng. | 1% 100 |
| TEST 2, TRAIN 1 | 6-0605 | Impinger [e.] | 6.0 ng. | 9 | 0.8 ng. | 0.1 ng. | 72% |
| TEST 2, TRAIN 1 | 6-0606 | Probe wash | 14 ng. | 8 | 1.4 ng. | 1.0 ng. | 122% |
| TEST 2, TRAIN 1 | 6-0607/<br>6-0608<br>(composite) | XAD-2 resin | 2.0 ng. | 9 | 0.25 ng. | 0.07 ng. | 100% |
| TEST 2, TRAIN 1 | 6-0609 | Florisil | 0 | 0 | 0 | 0.900<br>0.09 ng. | 85% |
| TEST 3, TRAIN 2 | 6-0643 | Impinger [f.] | 0 | 0 | 0 | 0.2 ng. | 100+% |
| TEST 3, TRAIN 2 | 6-0644 | Probe wash [f.] | 0 | 0 | 0 | 0.5 ng. | 60% |
| TEST 3, TRAIN 2 | 6-0645 | XAD-2 resin | 2.0 ng. | 8 | 0.2 ng. | 0.1 ng. | 72% |
| TEST 3, TRAIN 2 | 6-0646 | Florisil | 0 | 0 | 0 | 0.4 ng. | 50% 15 |

TABLE 10 (cont)

[a] Based on summation of the areas of all mass chromatographic peaks observed in a selected TCDF retention time window, while monitoring m/z 304 and 306. It is assumed that the instrument response determined by calibrating with an authentic 2,3,7,8-TCDF standard is the same for all TCDF isomers.

[b] The number of discrete mass chromatographic peaks observed in the TCDF window. Since all TCDF isomers are not available for determination of GC retention times, it is not known whether or not each peak represents more than one isomer. The number cited is therefore the minimum number of TCDF isomers which can be present in the sample.

[c] Determined on the basis of the mass chromatographic peak which has a retention time corresponding to that of the 2,3,7,8-TCDF isomer. Other TCDF isomers may also be included in this peak.

[d] Based on $^{37}Cl_4$-2,3,7,8-TCDD added as an internal standard.

[e] Upper layer (apparently hexane fraction) only.

[f] Sample contained only one layer which appeared to be the acetone-water layer; upper hexane layer observed in other samples was completely absent.

# TABLE 11

## WRIGHT STATE UNIVERSITY, BREHM LABORATORY, DAYTON, OHIO 45435

## TCDD ISOMERS DETERMINED IN STACK EFFLUENT SAMPLES FROM INCINERATION TESTS AT ENSCO, EL DORADO, ARKANSAS, AND ROLLINS ENVIRONMENTAL SERVICES, DEER PARK, TEXAS

| TEST AND SAMPLE TRAIN NUMBERS | TRW SAMPLE NUMBER | ORIGIN | TCDD ISOMERS DETECTED | % OF TOTAL TCDDs |
|---|---|---|---|---|
| Test 2, Train 1 | 6-0606 | Rollins Environmental Services | 1,3,6,8- | 25 |
| | | | 1,3,7,9 | 22 |
| | | | 1,3,6,9 | 9 |
| | | | 1,2,7,9 | 9 |
| | | | Others [a] | 35 |
| Test 2, Train 1 | 6-0560 | ENSCO | 1,3,6,8 | 20 |
| | | | 1,3,7,9 | 18 |
| | | | 1,3,6,9 | 3 |
| | | | 1,2,7,9 | 5 |
| | | | Others [b] | 54 |

---

[a] TCDDs are also observed at retention times corresponding to the 1,3,7,8-, 1,2,6,8-, and 1,2,6,9- isomers, but these isomers are apparently not completely resolved from several other TCDD isomers which could also account for these peaks.

[b] TCDDs are also observed at retention times corresponding to the 1,3,7,8-, 1,2,6,8-, and 1,2,3,4- isomers, but these peaks may also be accounted for by several other isomers.

## TABLE 12

## WRIGHT STATE UNIVERSITY, BREHM LABORATORY, DAYTON, OHIO 45435

## HIGH RESOLUTION GAS CHROMATOGRAPHIC-LOW RESOLUTION MASS SPECTROMETRIC DATA ON TOTAL CDDs AND CDFs (TETRACHLORINATED THROUGH OCTACHLORINATED) IN TEST 1, TRAIN 1 PROBE WASH SAMPLE (TRW NUMBER 6-0582) FROM INCINERATION TESTS AT ROLLINS ENVIRONMENTAL SERVICES, DEER PARK, TEXAS

| CDD/CDF [a] | NUMBER OF APPARENT ISOMERS [b] | QUANTITY OF TOTAL CDD/CDF DETECTED IN TOTAL SAMPLE(ng) [c] | MINIMUM DETECTABLE QUANTITY(ng) | % RECOVERY [d] |
|---|---|---|---|---|
| TCDD | e | -- | -- | 100 [f] |
| PCDD | 4 | 4 | 0.3 | -- |
| HxCDD | 2 | 1 | 0.5 | -- |
| HpCDD | 1 | 2 | 2 | 100 [f] |
| OCDD | 1 | 5 | 3 | -- |
| | | | | |
| TCDF | 7 | 5 | 0.2 | -- |
| PCDF | 6 | 30 | 0.3 | -- |
| HxCDF | 4 | 25 | 0.5 | -- |
| HpCDF | 2 | 12 | 2 | -- |
| OCDF | 1 | 10 | 3 | -- |

[a] Prefix designations are : T = tetra-; P = penta-; Hx = hexa-; Hp = hepta; O = octa- .

[b] Since only a limited number of CDD and CDF isomers are available (see Tables 1 and 2), it is not possible to demonstrate for most of the classes of CDDs and CDFs that all isomers of a given chlorinated group (for example, the pentachlorinated isomers; there are 14 PCDDs) are completely resolved by using the GC conditions employed here. Therefore, it is not certain that each peak of the family observed for a given chlorinated group corresponds to a single isomer. Hence, the terminology "apparent" is used which designates the number of GC peaks observed for a given chlorinated group of CDDs or CDFs.

[c] Results corrected for recovery on the basis of recovery of added internal standards.

[d] Recoveries for the CDDs were estimated on the basis of recovery of two internal standards added to the samples prior to processing. These standards are $^{37}Cl_4$-2,3,7,8-TCDD, the recovery of which was assumed to be indicative of the recoveries of native PCDDs and lower chlorinated CDDs (that is, mono- through penta- CDDs), and $^{37}Cl_4$-1,2,3,4,6,7,8-HpCDD, the recovery of which was assumed to be indicative of the recoveries of native HxCDDs and higher chlorinated CDDs (that is, hexa- through octa- CDDs). No isotopically-labelled CDFs were available, and so the recoveries of CDFs could not be directly assessed. However, recoveries of CDFs are probably on the same order as the corresponding CDDs.

TABLE 12 (cont)

[e] Not determined in the HRGC-LRMS analyses; these data were obtained by LRGC-HRMS and are reported in Table 7.

[f] Refers to recovery of $^{37}$Cl-labelled standards mentioned in Note d.

## TABLE 13

## WRIGHT STATE UNIVERSITY, BREHM LABORATORY, DAYTON, OHIO 45435

## HIGH RESOLUTION GAS CHROMATOGRAPHIC-LOW RESOLUTION MASS SPECTROMETRIC DATA ON TOTAL CDDs AND CDFs (TETRACHLORINATED THROUGH OCTACHLORINATED) IN TEST 2, TRAIN 1 IMPINGER SAMPLE (TRW NUMBER 6-0560) FROM INCINERATION TESTS AT ENSCO, EL DORADO, ARKANSAS

| CDD/CDF [a] | NUMBER OF APPARENT ISOMERS [b] | QUANTITY OF TOTAL CDD/CDF DETECTED IN TOTAL SAMPLE (ng) [c] | MINIMUM DETECTABLE QUANTITY (ng) | % RECOVERY [d] |
|---|---|---|---|---|
| TCDD | e | -- | -- | 100 [f] |
| PCDD | -- | -- | 1 | -- |
| HxCDD | -- | -- | 2 | -- |
| HpCDD | -- | -- | 6 | 100 [f] |
| OCDD | -- | -- | 8 | -- |
| | | | | |
| TCDF | 3 | 4 | 0.5 | -- |
| PCDF | 6 | 20 | 1 | -- |
| HxCDF | -- | -- | 2 | -- |
| HpCDF | -- | -- | 6 | -- |
| OCDF | -- | -- | 8 | -- |

[a] Prefix designations are: T = tetra-; P = penta-; Hx = hexa-; Hp = hepta-; O = octa- .

[b] Since only a limited number of CDD and CDF isomers are available (see Tables 1 and 2), it is not possible to demonstrate for most of the classes of CDDs and CDFs that all isomers of a given chlorinated group (for example, the pentachlorinated isomers; there are 14 PCDDs) are completely resolved by using the GC conditions employed here. Therefore, it is not certain that each peak of the family observed for a given chlorinated group corresponds to a single isomer. Hence, the terminology "apparent" is used which designates the number of GC peaks observed for a given chlorinated group of CDDs or CDFs.

[c] Results corrected for recovery on the basis of recovery of added internal standards.

[d] Recoveries for the CDDs were estimated on the basis of recovery of two internal standards added to the samples prior to processing. These standards are $^{37}Cl_4$-2,3,7,8-TCDD, the recovery of which was assumed to be indicative of the recoveries of native PCDDs and lower chlorinated CDDs (that is, mono- through penta- CDDs), and $^{37}Cl_4$-1,2,3,4,6,7,8-HpCDD, the recovery of which was assumed to be indicative of the recoveries of native HxCDDs and higher chlorinated CDDs (that is, hexa- through octa- CDDs). No isotopically-labelled CDFs were available, and so the recoveries of CDFs could not be directly assessed. However, recoveries of CDFs are probably on the same order as the corresponding CDDs.

TABLE 13 (cont)

[e] Not determined in the HRGC-LRMS analyses; these data were obtained by LRGC-HRMS and are reported in Table 8.

[f] Refers to recovery of $^{37}$Cl-labelled standards mentioned in Note d.

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## TABLE 14

## WRIGHT STATE UNIVERSITY, BREHM LABORATORY, DAYTON, OHIO 45435

## HIGH RESOLUTION GAS CHROMATOGRAPHIC-LOW RESOLUTION MASS SPECTROMETRIC DATA ON PCBs IN TEST 2, TRAIN 1 FLORISIL SAMPLE (TRW NUMBER 6-0609) FROM INCINERATION TESTS AT ROLLINS ENVIRONMENTAL SERVICES, DEER PARK, TEXAS

| CLASS OF CHLORINATED PCB (NO. OF CHLORINE SUBSTITUENTS) | NUMBER OF APPARENT ISOMERS[a] | QUANTITY OF PCBs DETECTED IN TOTAL SAMPLE (ng) | MINIMUM DETECTABLE QUANTITY (ng) |
|---|---|---|---|
| Monochlorinated (1) | -- | -- | 0.1 |
| Dichlorinated (2) | 3 | 10 | 0.3 |
| Trichlorinated (3) | 8 | 15 | 0.3 |
| Tetrachlorinated (4) | 4 | 3 | 0.5 |
| Pentachlorinated-Decachlorinated (5-10) | -- | c | -- |

[a] Only a limited number of PCB isomers are available for use in establishing GC retention times and sensitivities for PCBs, and so it could not be demonstrated that all isomers of a given chlorinated class are resolved using the GC conditions employed here. Therefore, it is not certain that each peak of the family observed for a given chlorinated group corresponds to a single isomer. Hence, the terminology "apparent" is used, which designates the number of GC peaks observed for a given chlorinated group of PCBs.

[b] Assumes that the sensitivities of all isomers of a given chlorinated class are the same. These data are not corrected for recovery, since no isotopically-labelled PCBs were available to establish recoveries for the method used.

[c] Some $Cl_5$- $Cl_{10}$ PCBs are probably present, but there were too many interferring MS peaks to reliably determine these.

DS-50 CROSS SCAN REPORT, RUN: VER100005 474

* 256-259 # 319-322 O 327-328

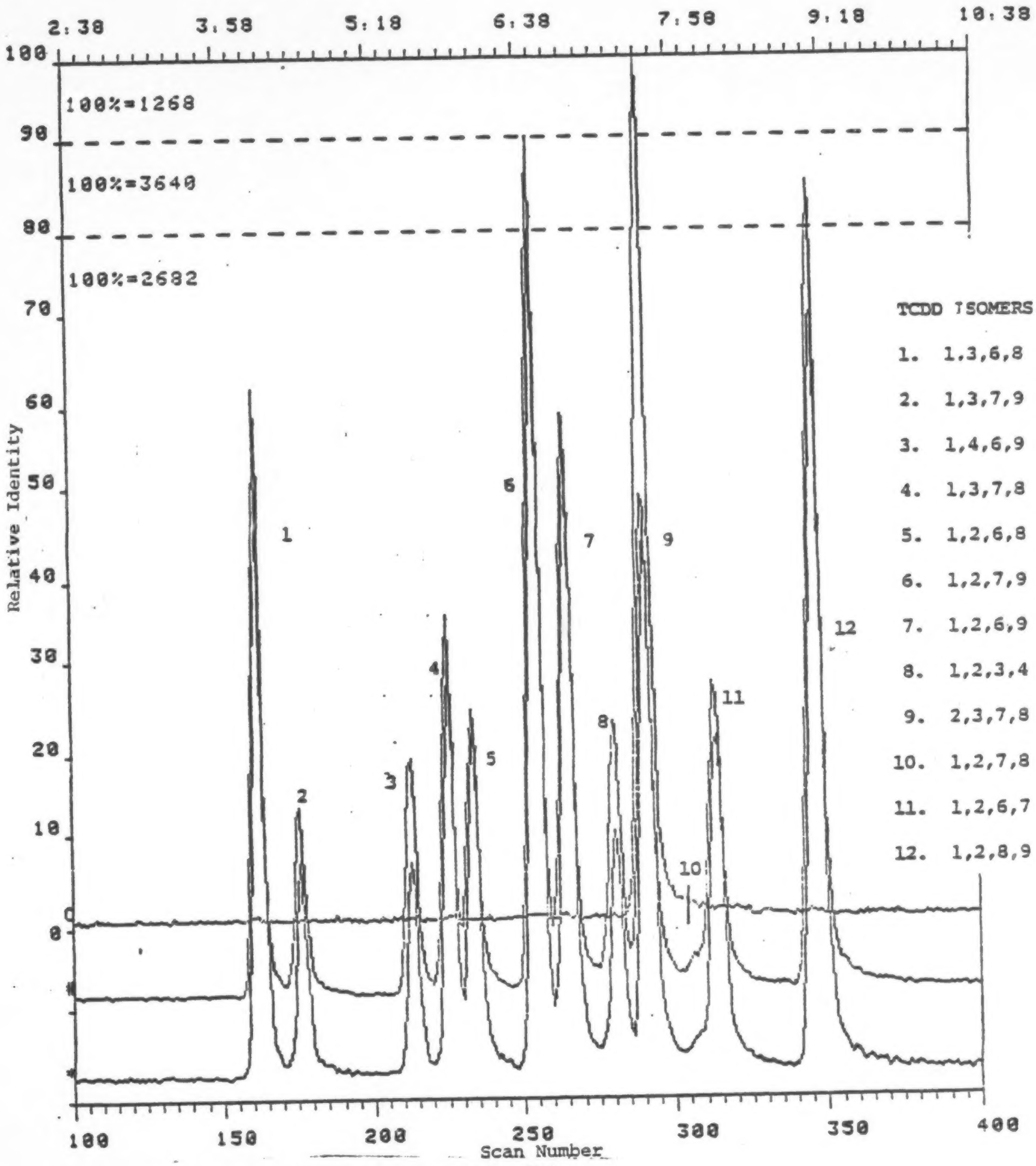

Figure 1. WSU-Brehm Laboratory, Dayton, Ohio
Selected-Ion Mass Chromatograms Obtained By HRGC-LRMS For 12-Isomer TCDD Standard Mixture. Masses Monitored Are Indicated At Top of Page Along With Corresponding Symbols For Each Trace Shown. Numbering of Peaks Corresponds To Isomer Identifications Shown at Right.

475

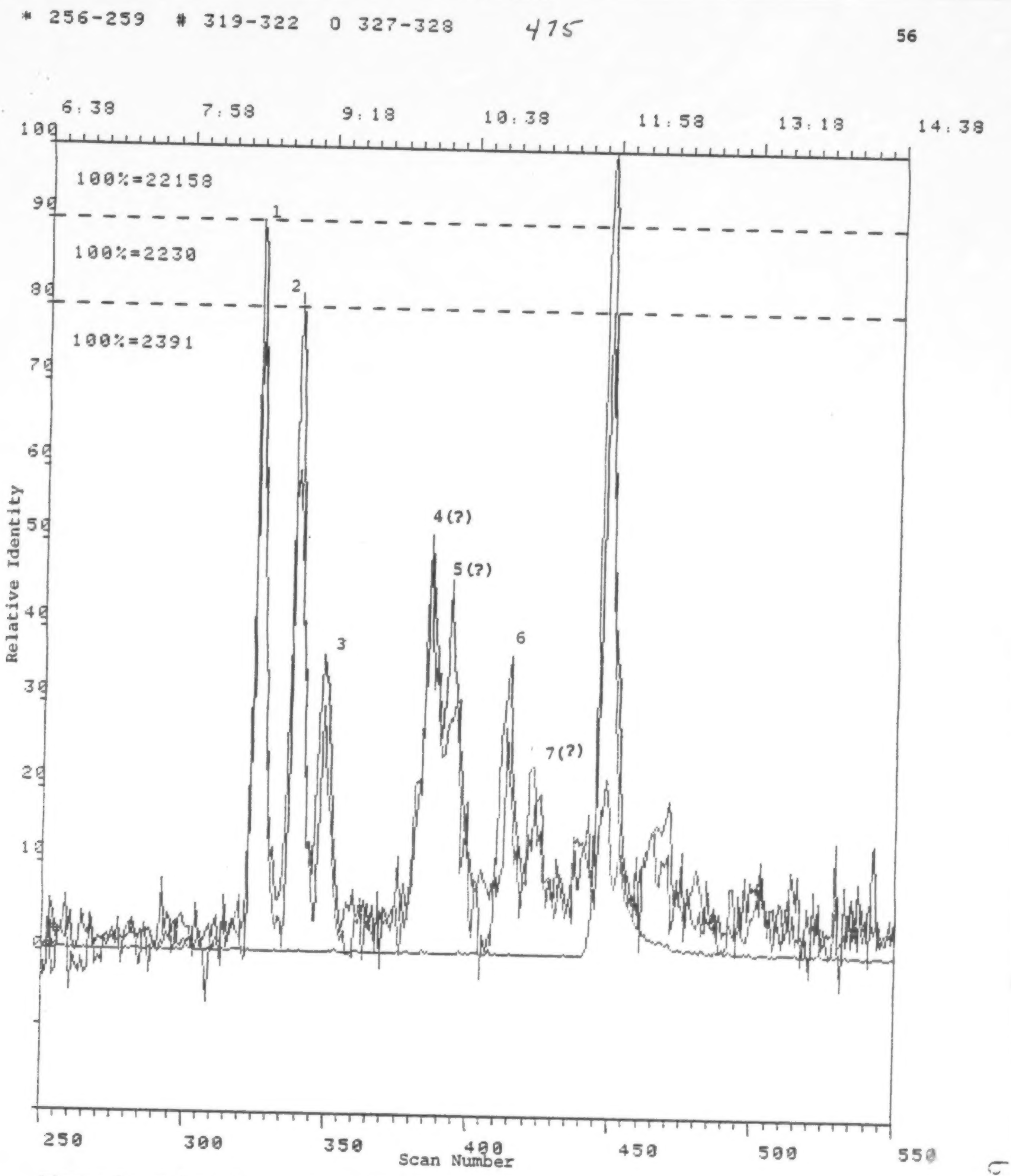

Figure 2. Selected Ion Monitoring Mass Chromatograms Obtained From HRGC-LRMS Analysis of Rollins Test 2, Train 1 Probe Wash Sample (TRW Number 6-0606) Showing TCDD Isomer Peaks. The Numbering Used To Identify Isomer Peaks Corresponds To That Indicated In Figure 1. $^{37}Cl_4$-2,3,7,8-TCDD Was Added As Internal Standard.

* 319-322 # 327-328

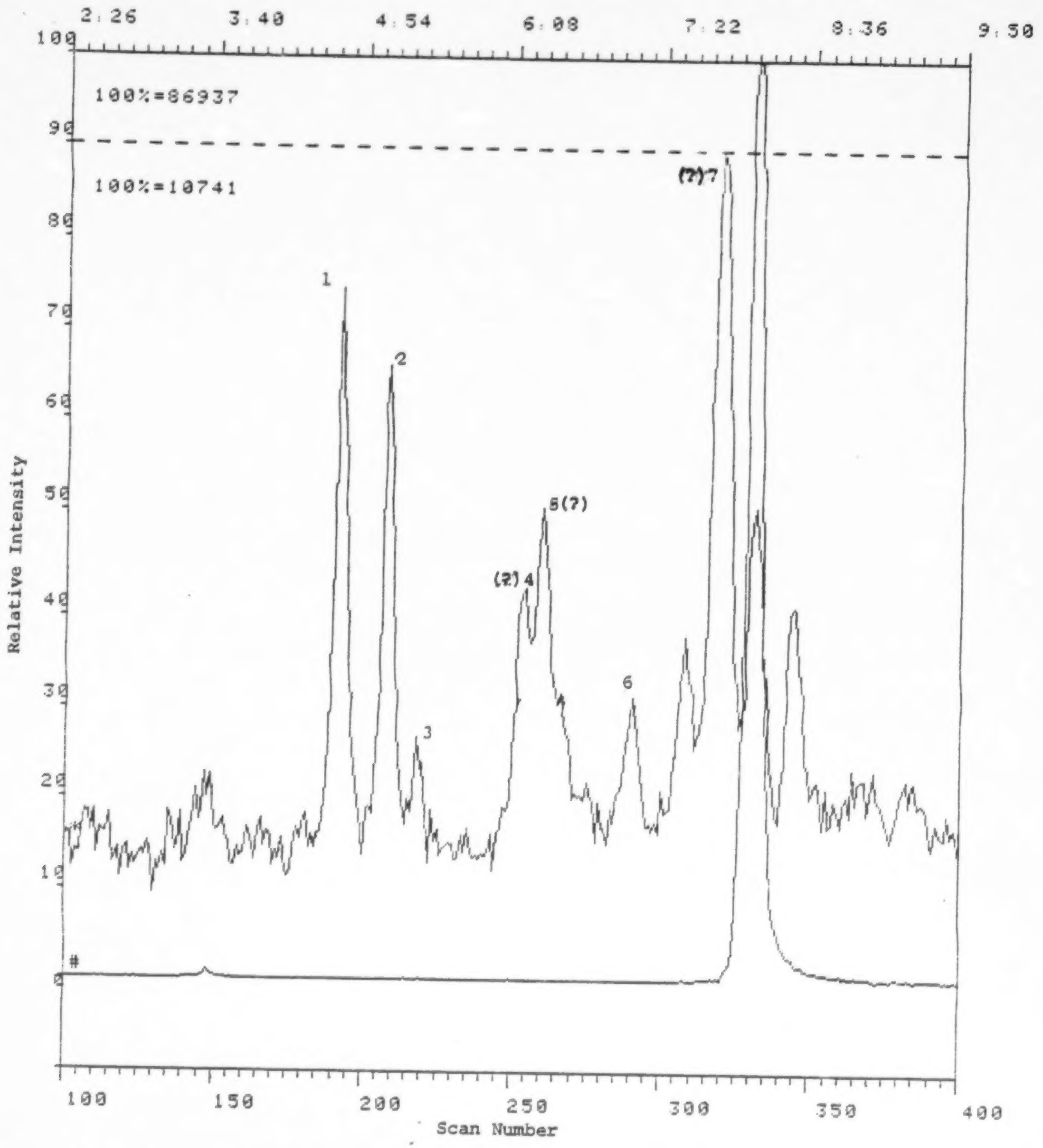

Figure 3. Selected Ion Monitoring Mass Chromatograms Obtained From HRGC-LRMS Analysis of ENSCO Test 2, Train 1 Impinger Sample (TRW 6-0560) Showing TCDD Isomer Peaks. The Numbering Used To Identify Isomer Peaks Corresponds To That Indicated In Figure 1. $^{37}Cl_4$-2,3,7,8-TCDD was Added To Sample As Internal Standard.

* 303-304 # 305-306

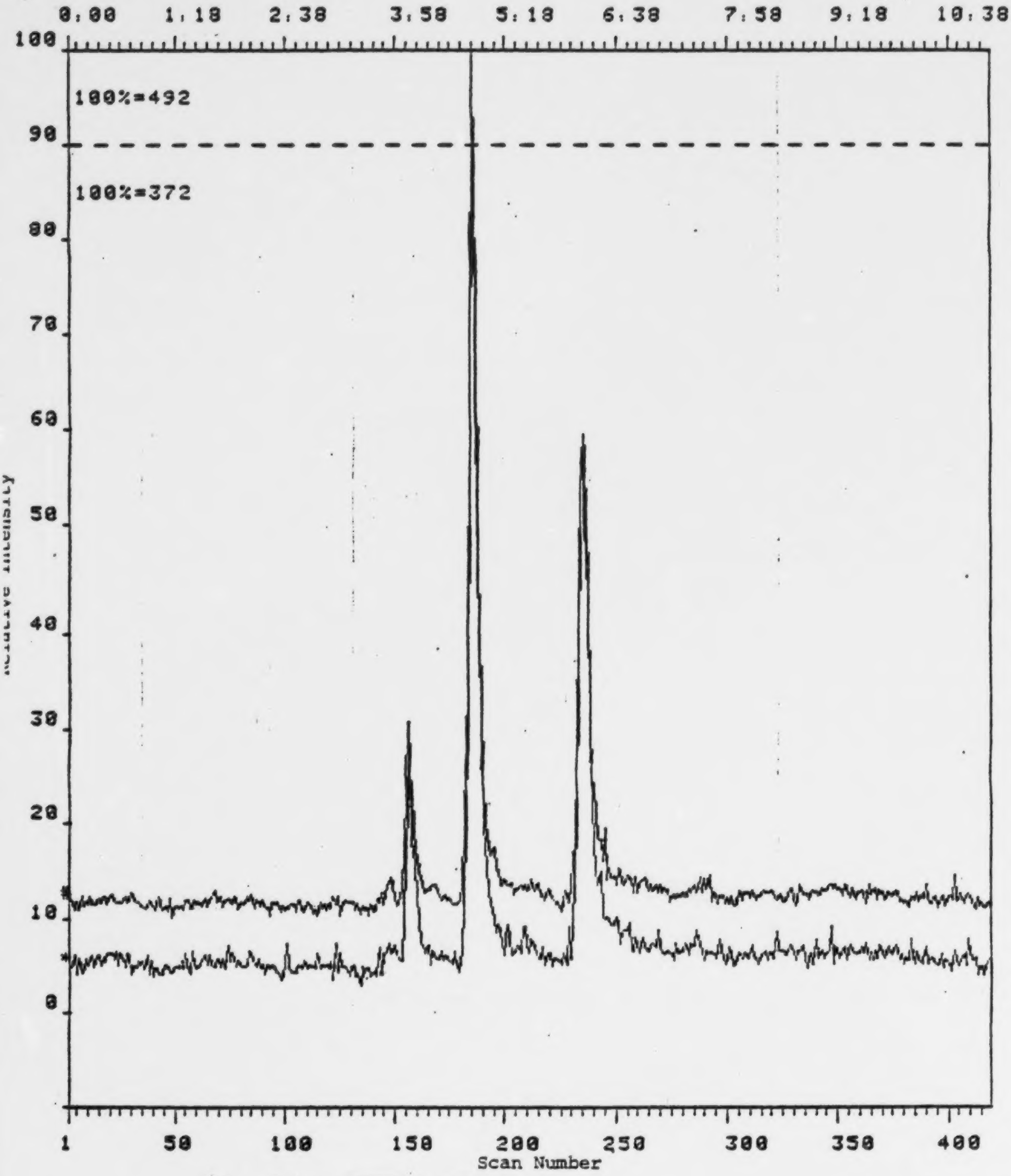

Figure 4. HRGC-MS Mass Chromatograms Results Obtained For Calibration Standard Containing Tetrachlorodibenzofurans (2,3,7,8-TCDF, 1,2,4,8-TCDF, 2,3,6,8-TCDF). Ions Monitored And Corresponding Identification Symbol For Traces Is Shown At Top of Page.

478

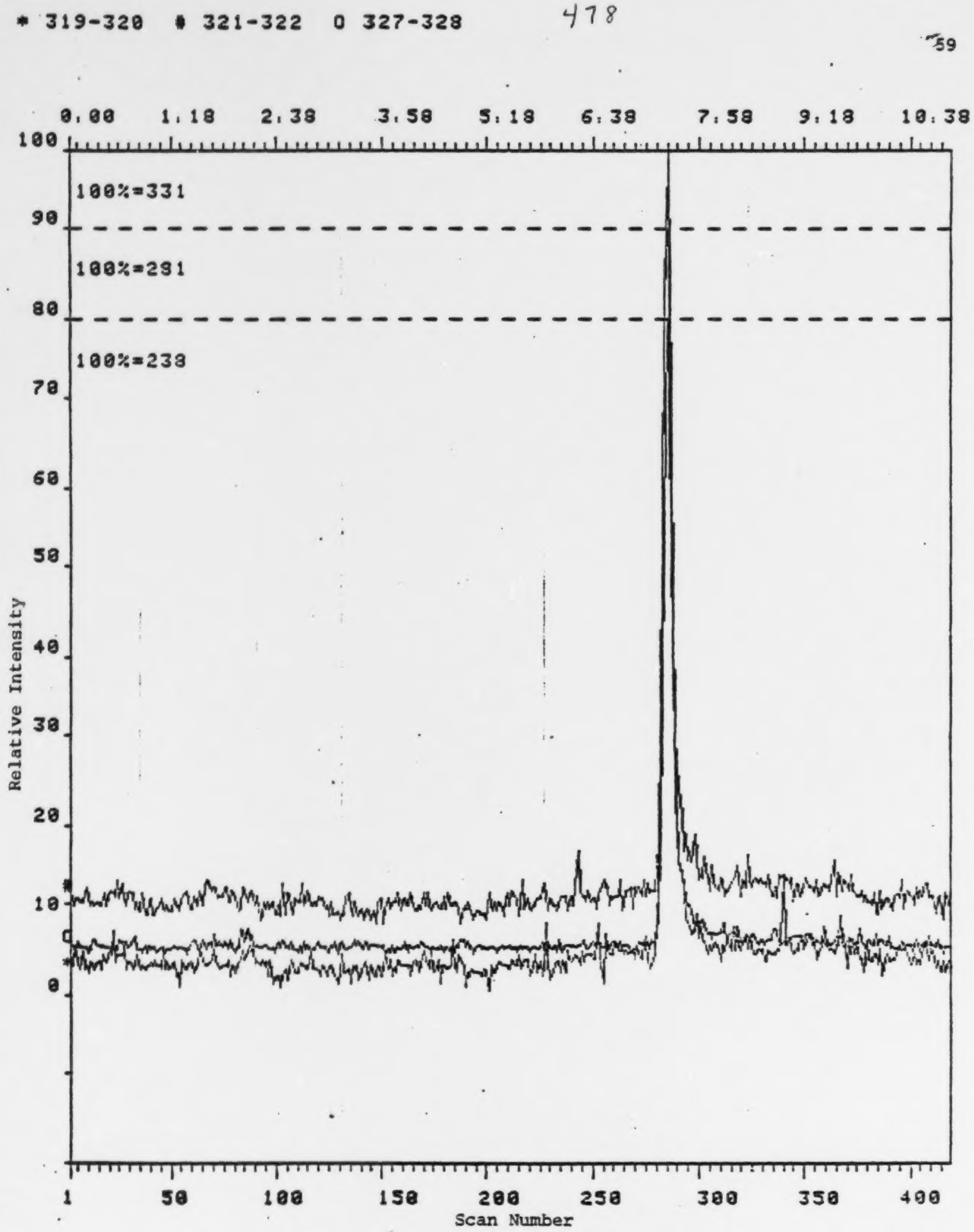

Figure 5. HRGC-LRMS Mass Chromatograms Obtained For Calibration Standard Containing $^{37}Cl_4$-2,3,7,8-TCDD.

479

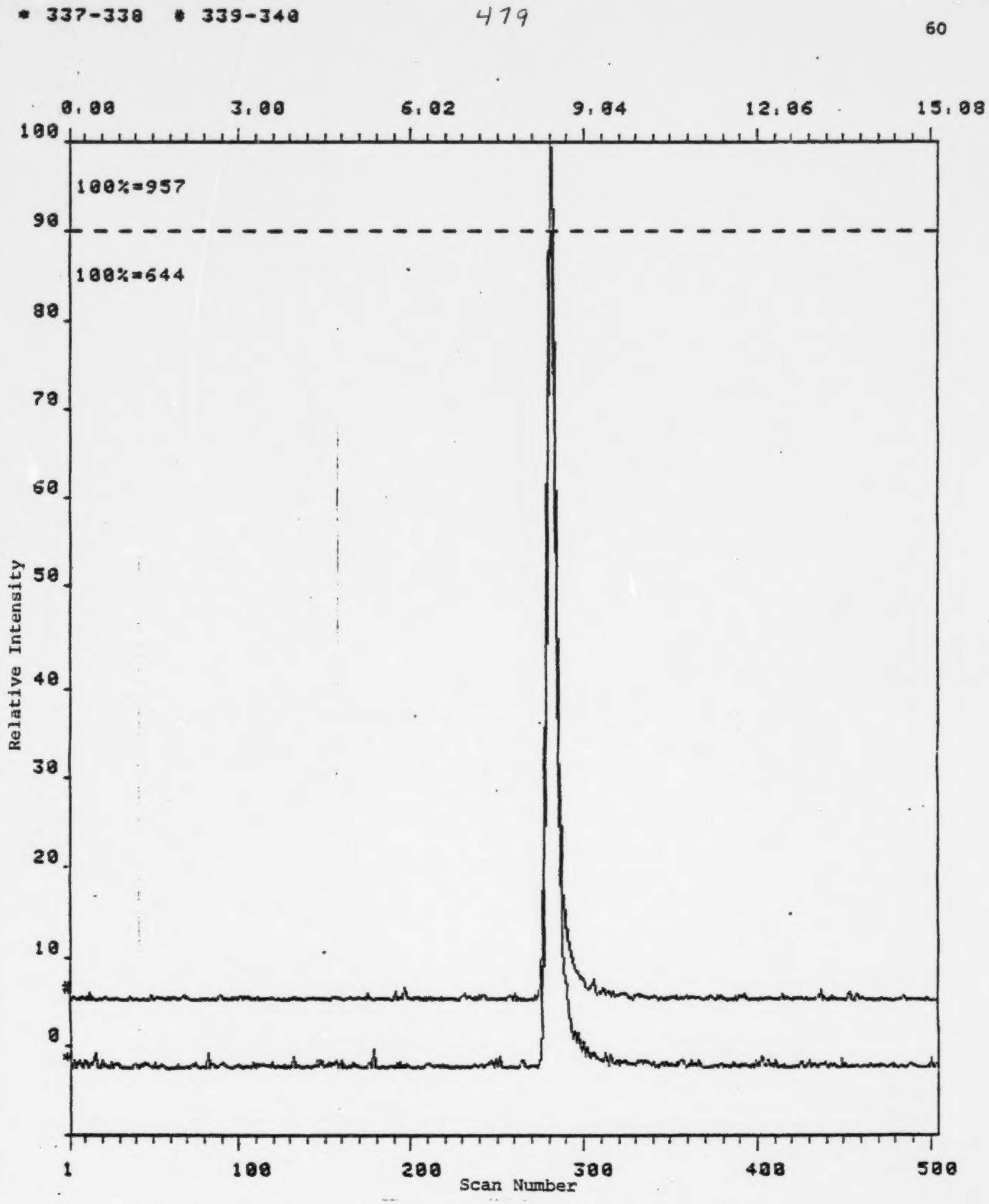

Figure 6. HRGC-LRMS Mass Chromatograms Obtained For Calibration Standard Containing Pentachlorodibenzofuran (1,2,4,7,8-PCDF).

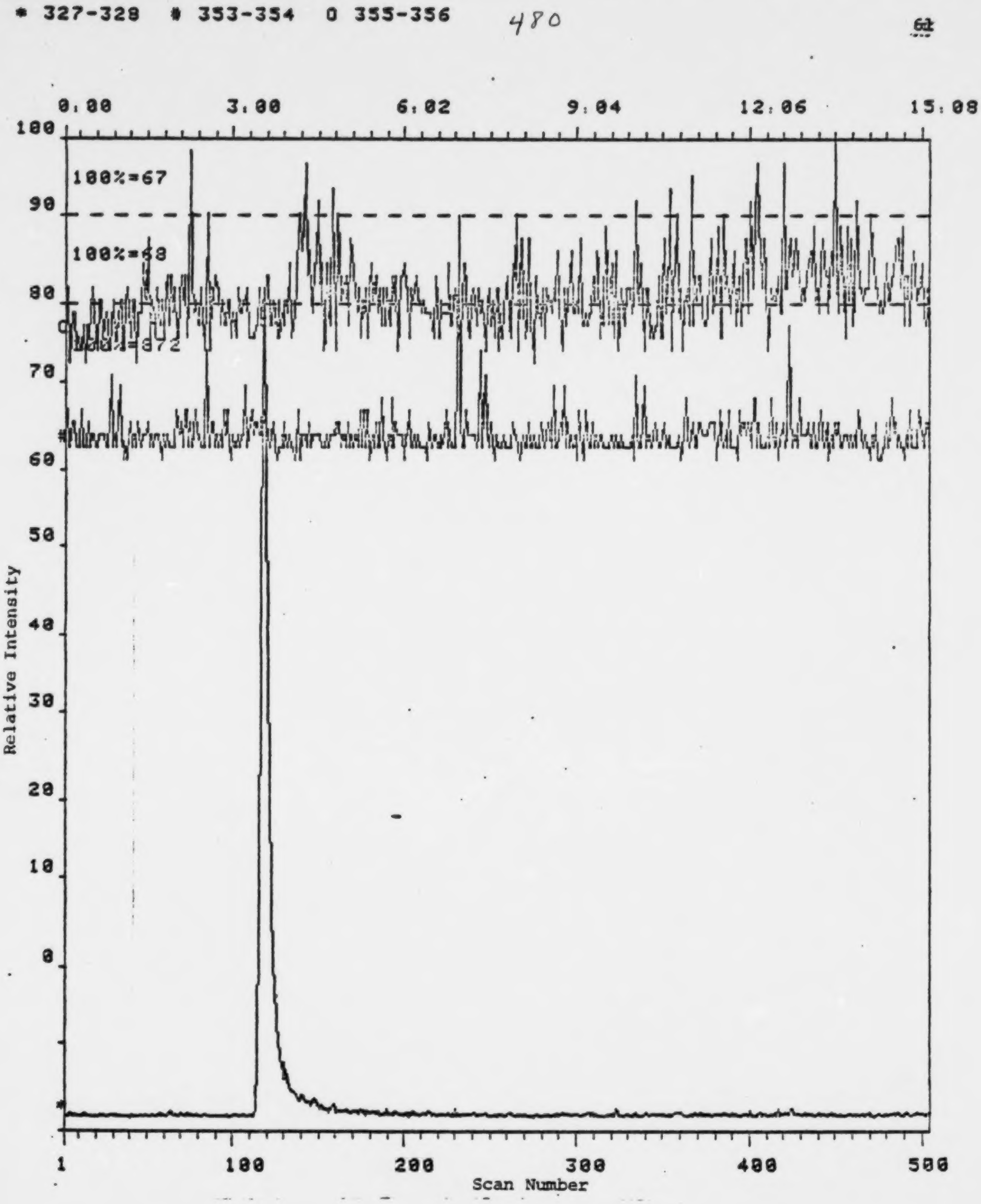

Figure 7. HRGC-LRMS Mass Chromatograms Obtained For Calibration Standard Containing $^{37}Cl_4$-2,3,7,8-TCDD with Instrument also Configured For Detection of Pentachlorodibenzo-p-Dioxins.

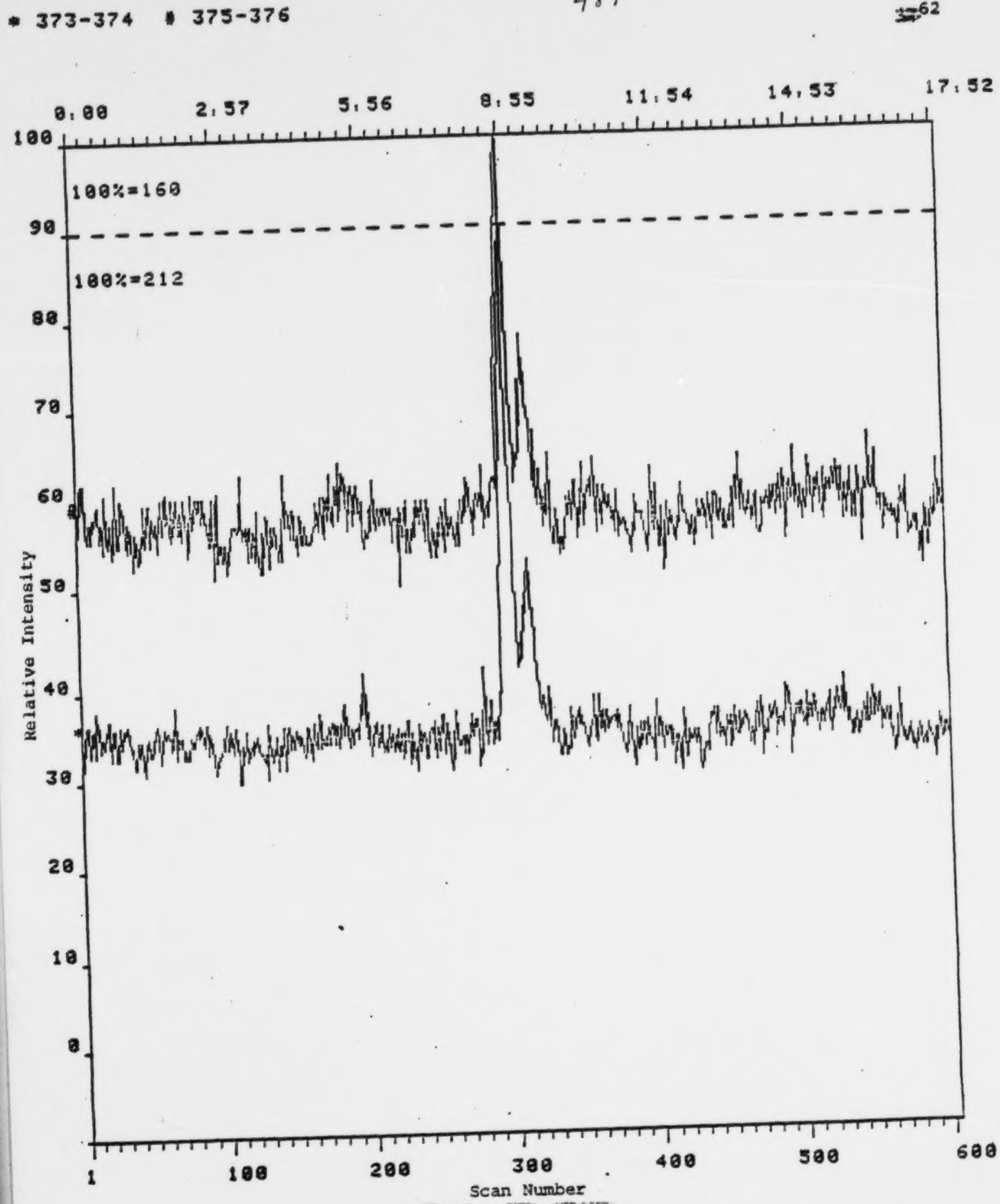

Figure 8. HRGC-LRMS Mass Chromatograms Obtained For Calibration Standard Containing Hexachlorodibenzofurans (1,2,4,6,7,9-HxCDF).

DS-50 CROSS SCAN REPORT, RUN: ACC6B0005 482

* 389-390 # 391-392

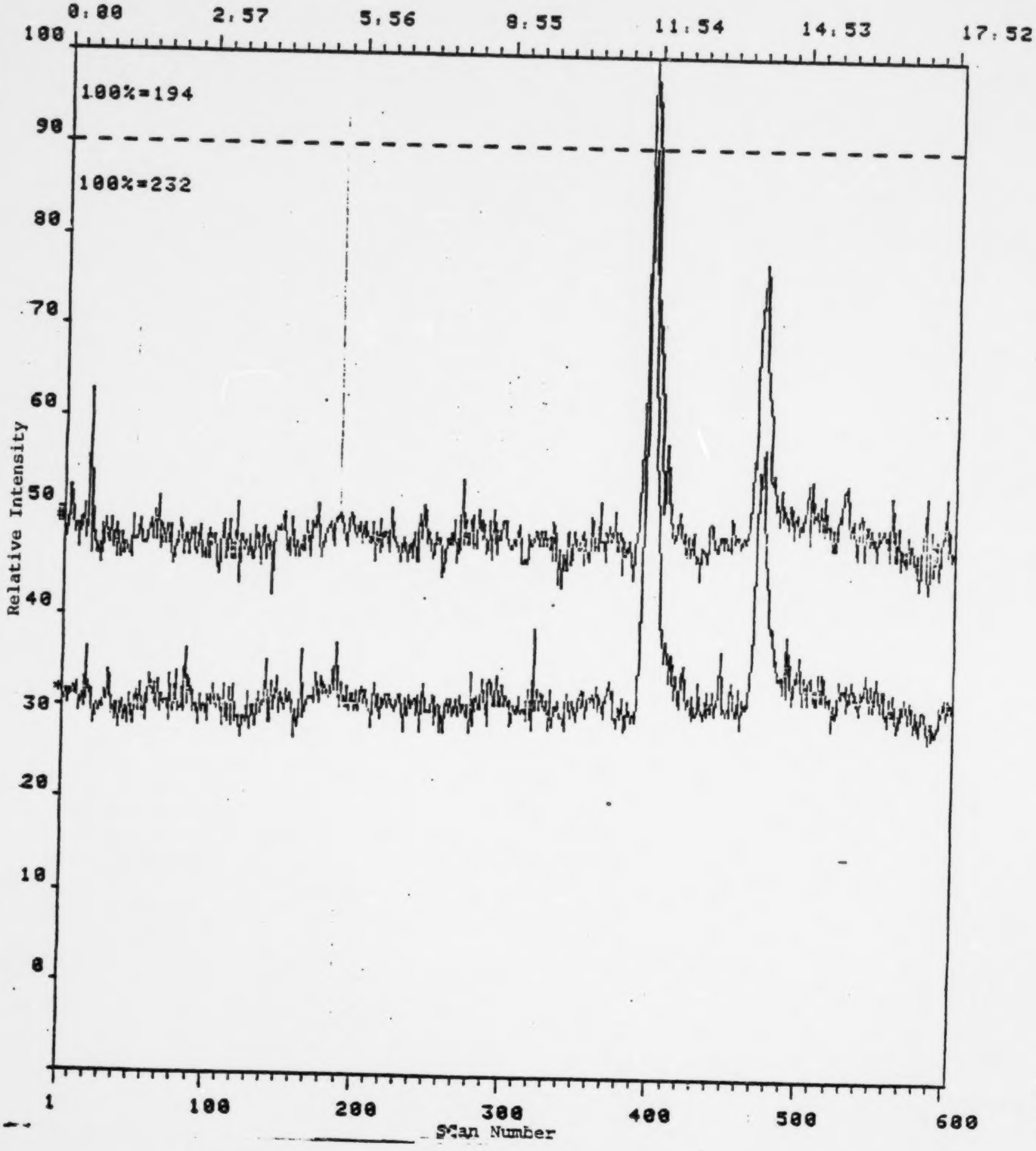

Figure 9. HRGC-LRMS Mass Chromatograms Obtained For Calibration Standard Containing Hexachlorodibenzo-p-Dioxins Including (1,2,3,4,7,8-HxCDD).

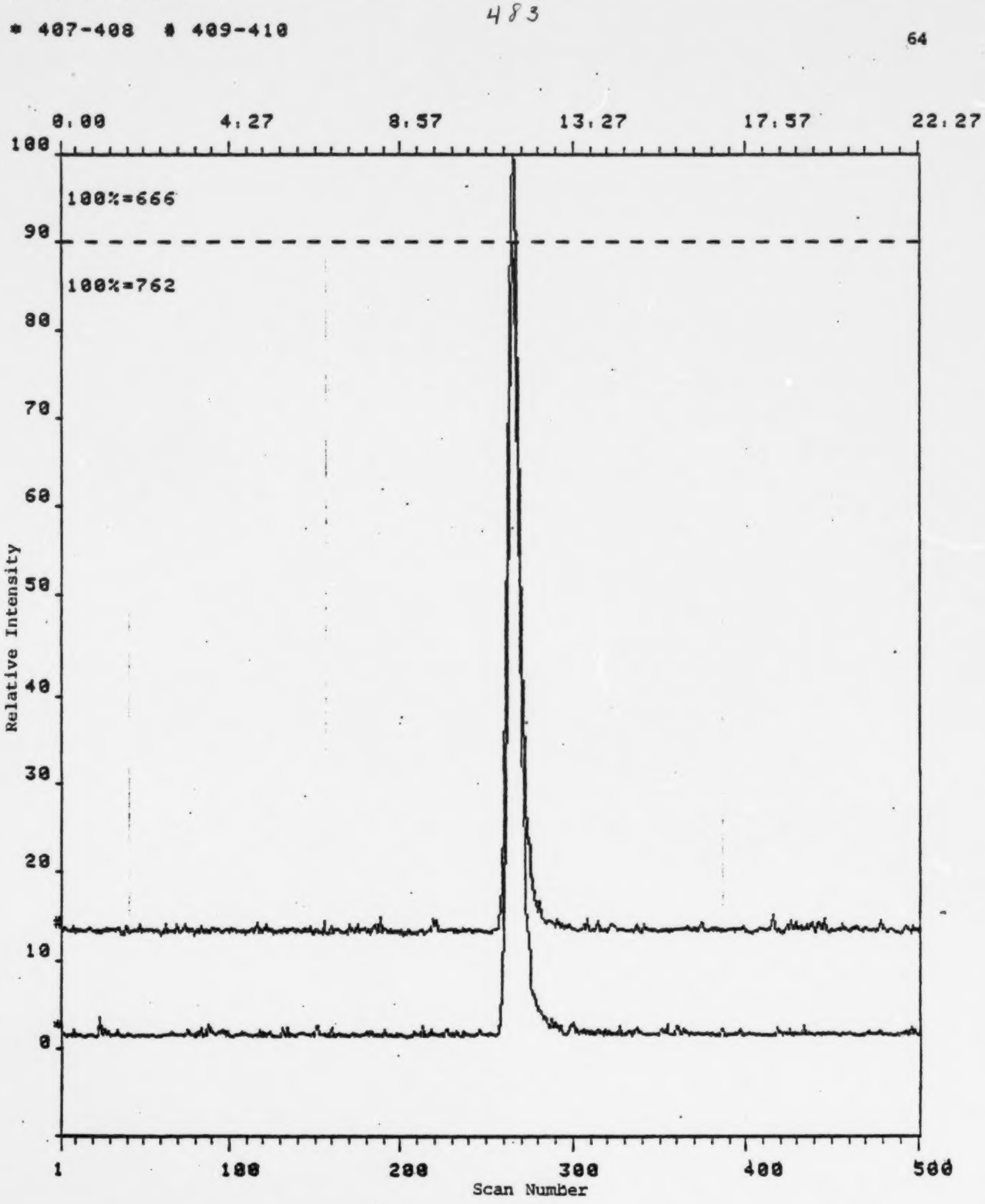

Figure 10. HRGC-LRMS Mass Chromatograms Obtained For Calibration Standard Containing Heptachlorodibenzofuran (1,2,3,4,6,8,9-HpCDF).

484

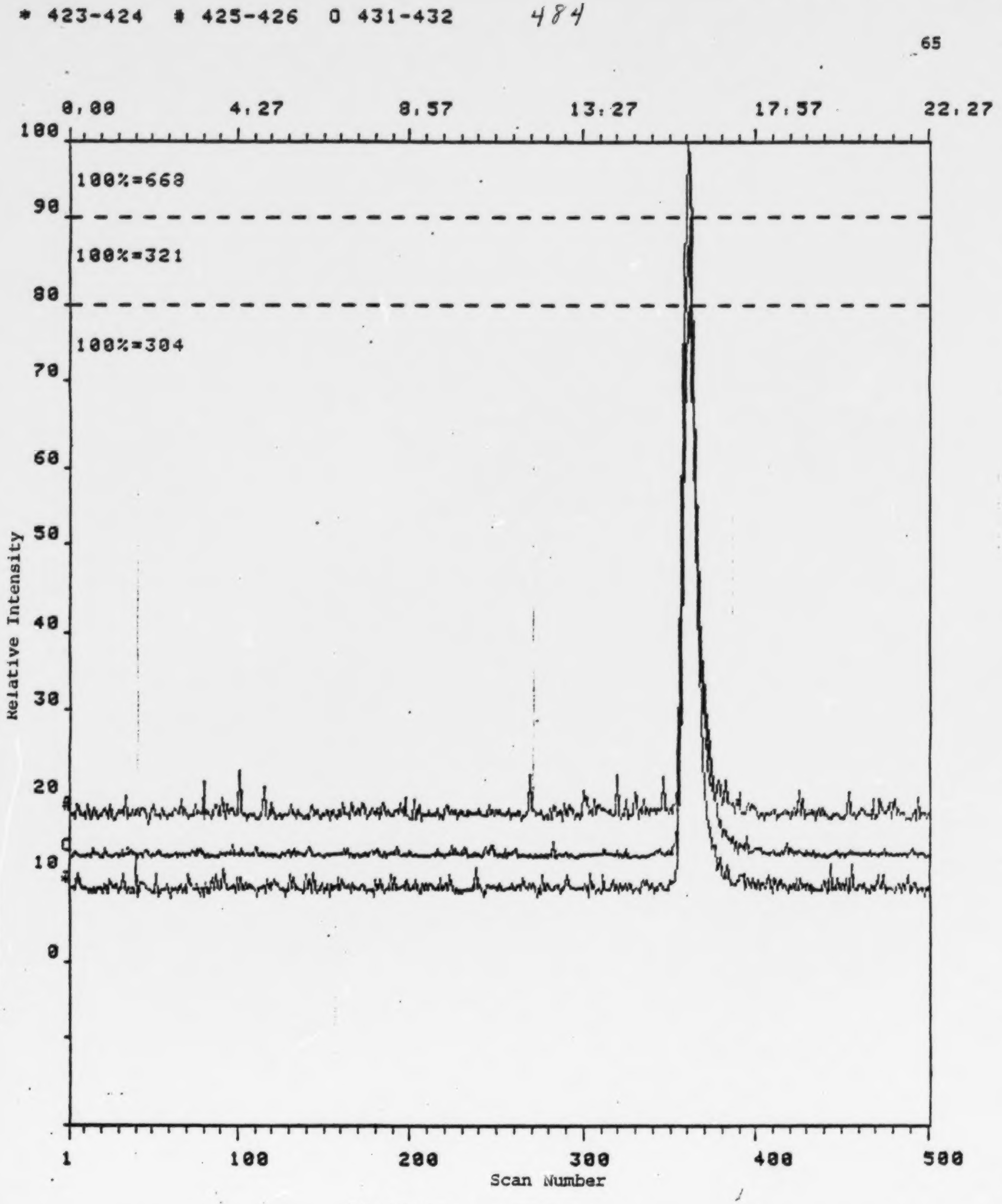

Figure 11. HRGC-LRMS Mass Chromatograms Obtained For Calibration Standard Containing Heptachlorodibenzo-p-Dioxins (1,2,3,4,6,7,8-HpCDD and $^{37}Cl_4$-1,2,3,4,6,7,8-HpCDD).

DS-50 CROSS SCAN REPORT, RUN, ACC8B0003 485

* 441-442 # 443-444

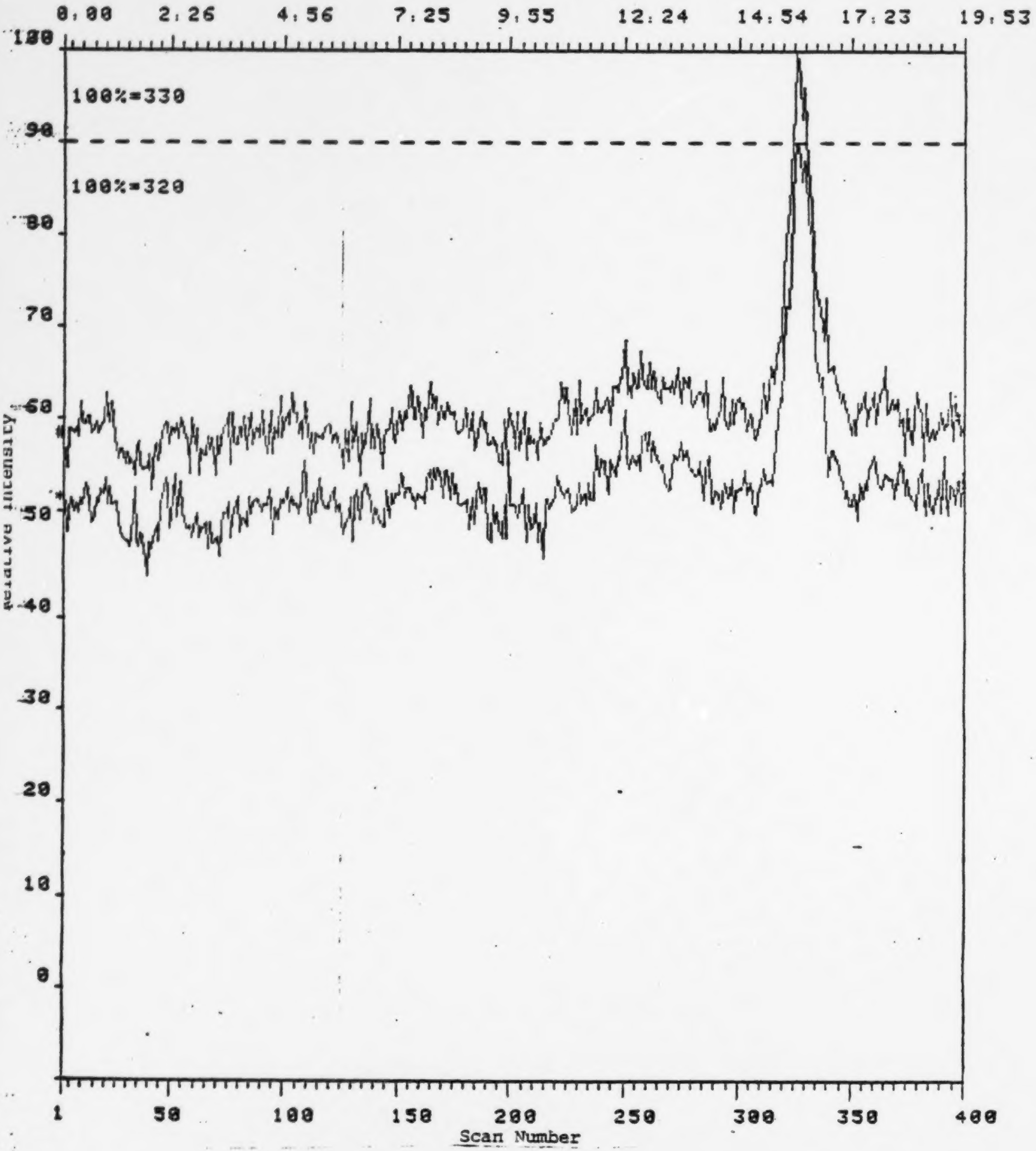

Figure 12. HRGC-LRMS Mass Chromatograms Obtained For Calibration Standard Containing Octachlorodibenzofuran.

* 457-458 # 459-460

486

.67

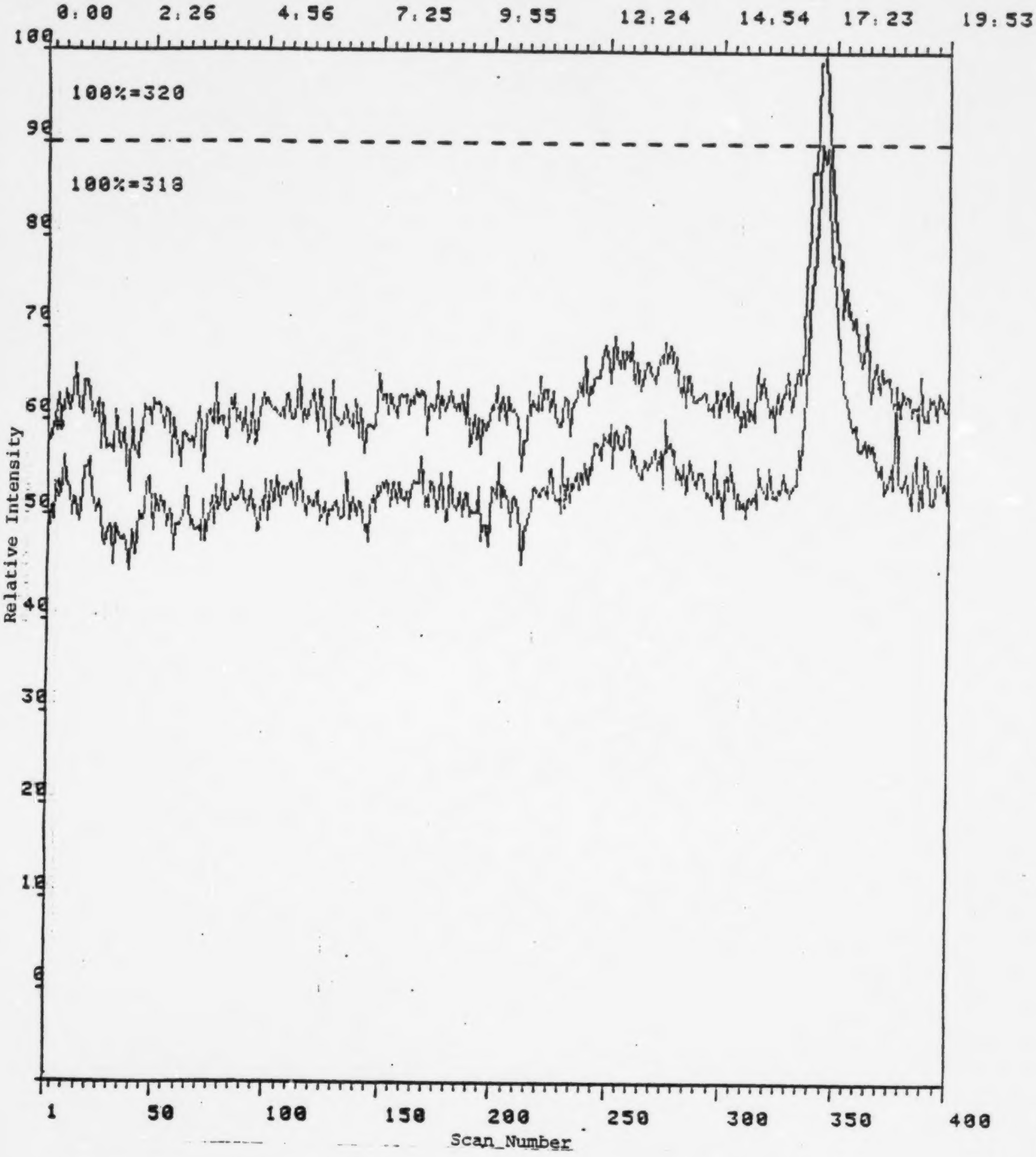

Figure 13. HRGC-LRMS Mass Chromatograms Obtained For Calibration Standard Containing Octachlorodibenzo-p-Dioxin.

DS-55 CROSS SCAN REPORT, RUN: RESDFC0003

* 303-306

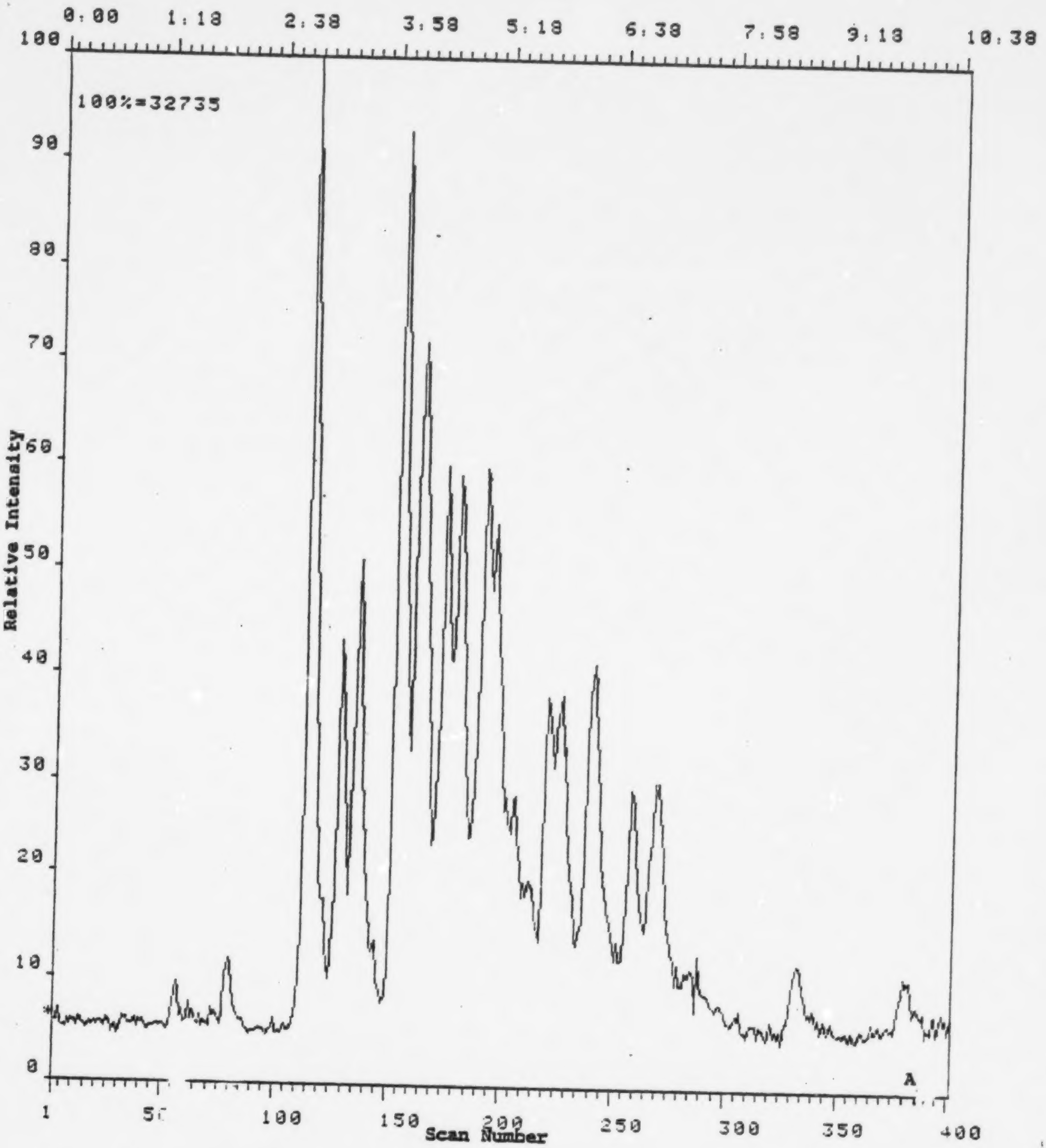

Figure 14. HRGC-LRMS Mass Chromatogram Obtained In Analysis of TCDFs In Rollins Test 2, Train 1 Probe Wash Sample (TRW Number 6-0606).

DS-55 CROSS SCAN REPORT, RUN: RESDFD0002

488

* 337-340

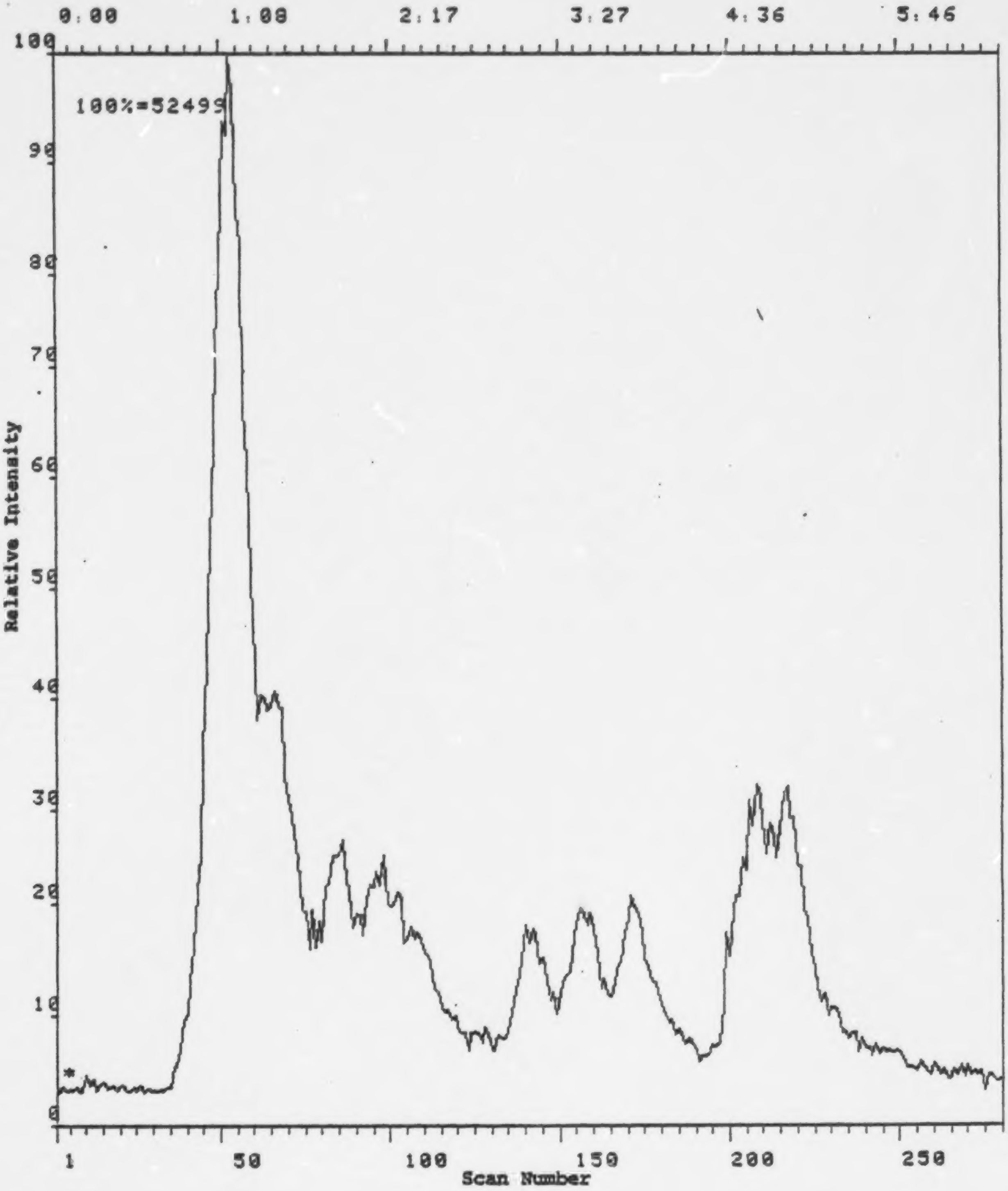

Figure 15. HRGC-LRMS Mass Chromatogram Obtained In Analysis Of PCDFs In Rollins Test 2, Train 1 Probe Wash Sample (TRW Number 6-0606).

DS-55 CROSS SCAN REPORT, RUN: RESDFD0002

489

* 353-356

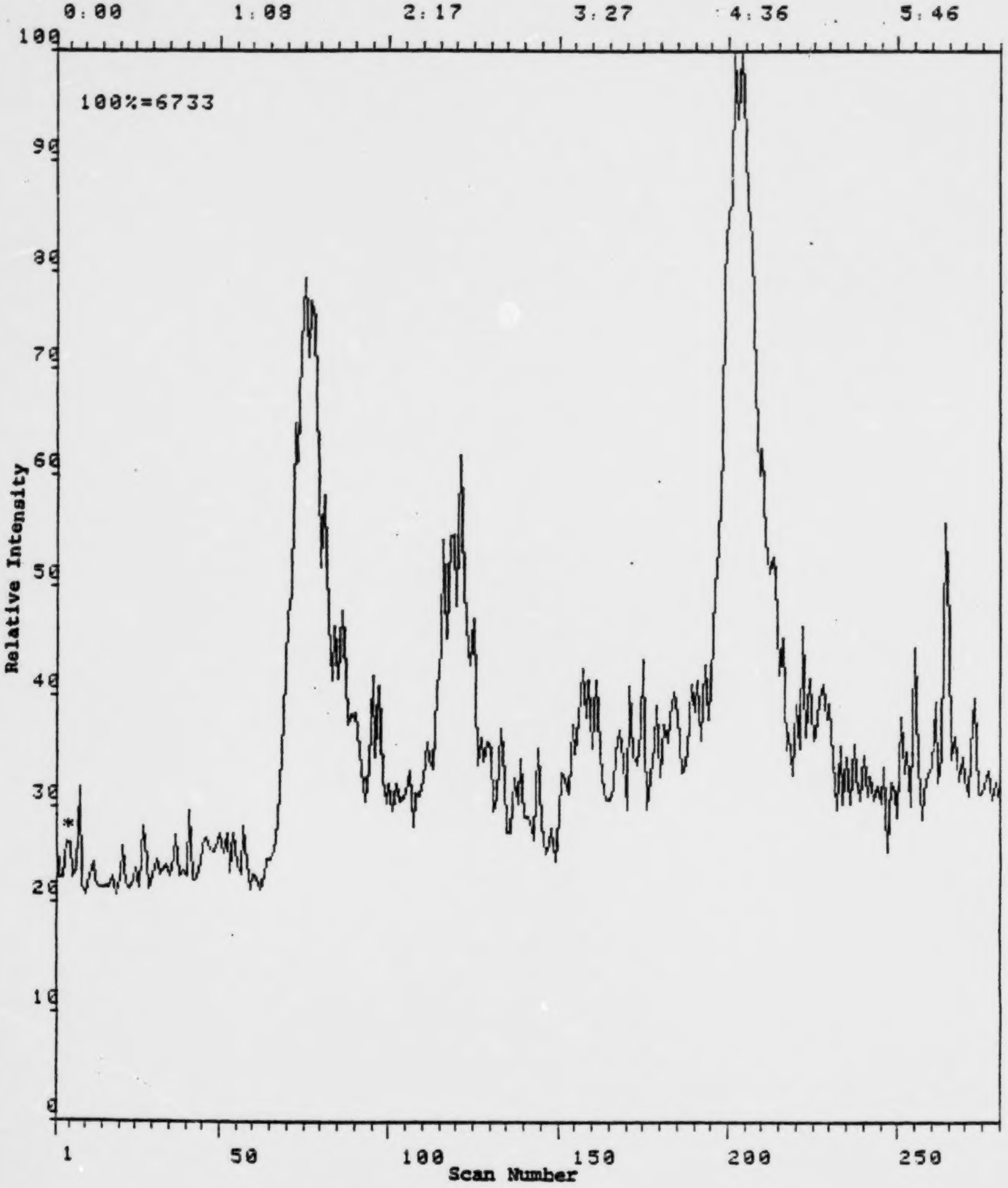

**Figure 16.** HRGC-LRMS Mass Chromatogram Obtained In Analysis of PCDDs In Rollins Test 2, Train 1 Probe Wash Sample (TRW Number 6-0606).

DS-55 CROSS SCAN REPORT, RUN: RESDEF0001 71

* 373-376

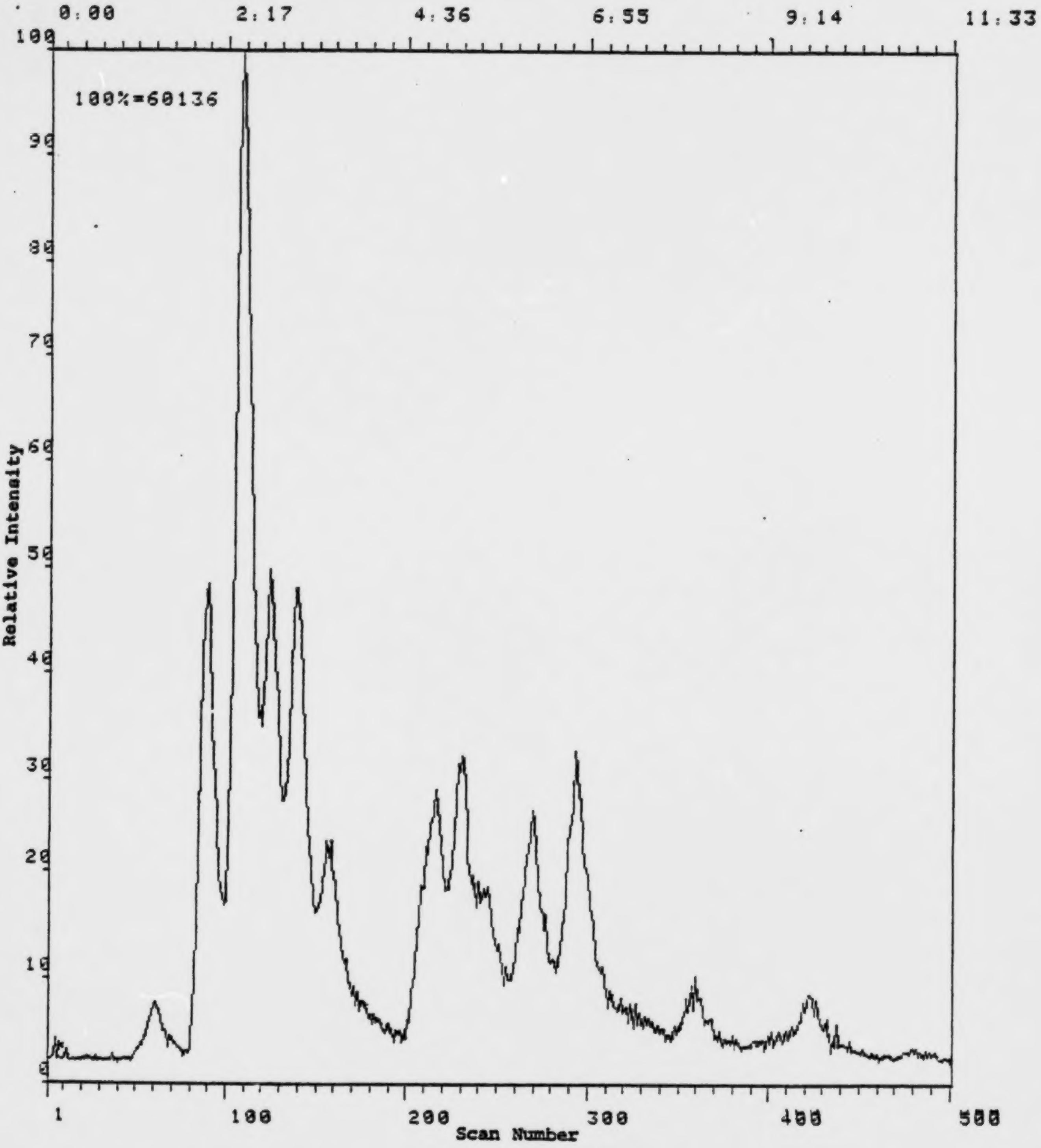

Figure 17. HRGC-LRMS Mass Chromatogram Obtained In Analysis of HxCDFs In Rollins Test 2, Train 1 Probe Wash Sample (TRW Number 6-0606).

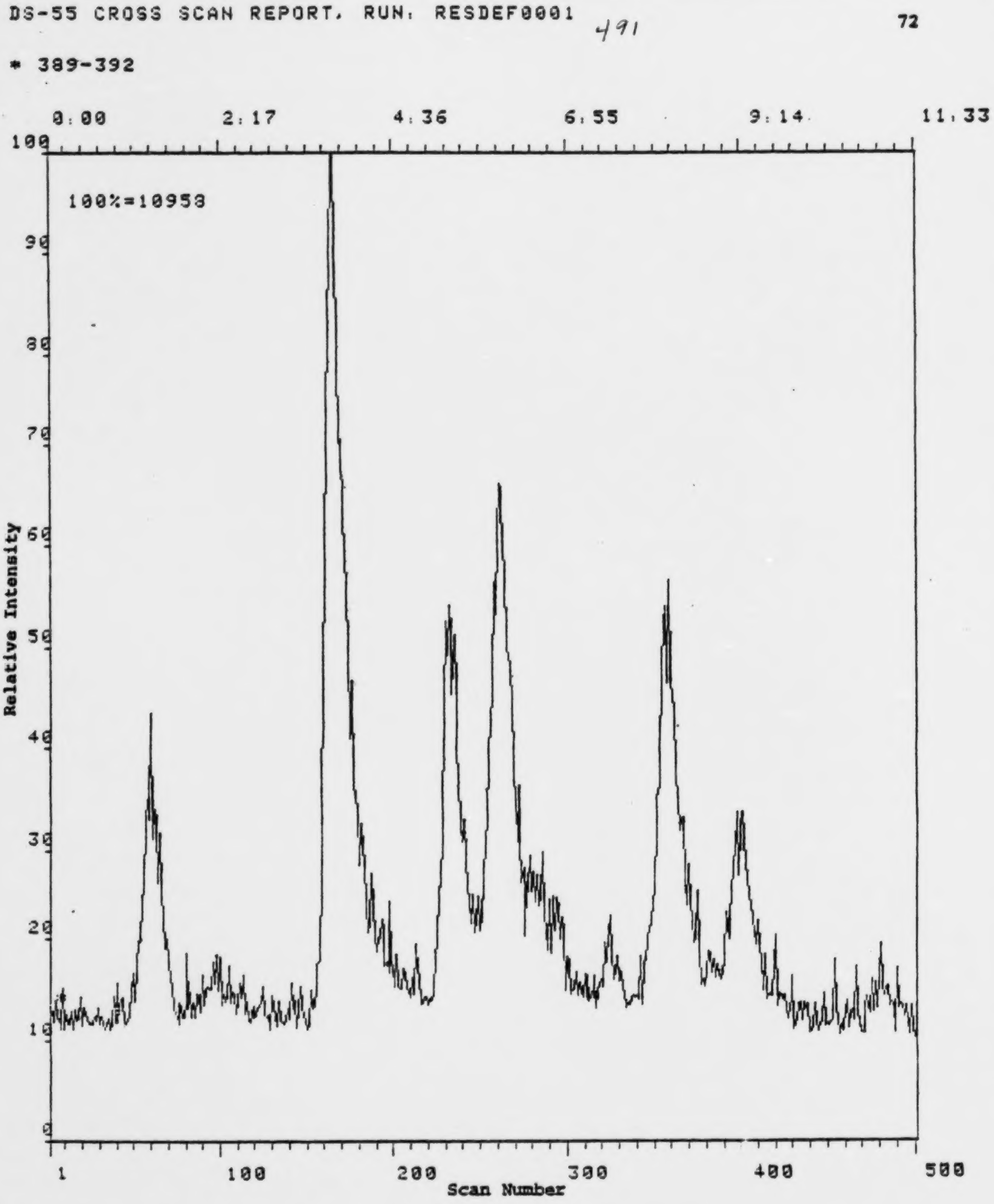

Figure 18. HRGC-LRMS Mass Chromatogram Obtained In Analysis of HxCDDs In Rollins Test 2, Train 1 Probe Wash Sample (TRW Number 6-0606).

DS-55 CROSS SCAN REPORT, RUN: RESDFF0002

* 407-410

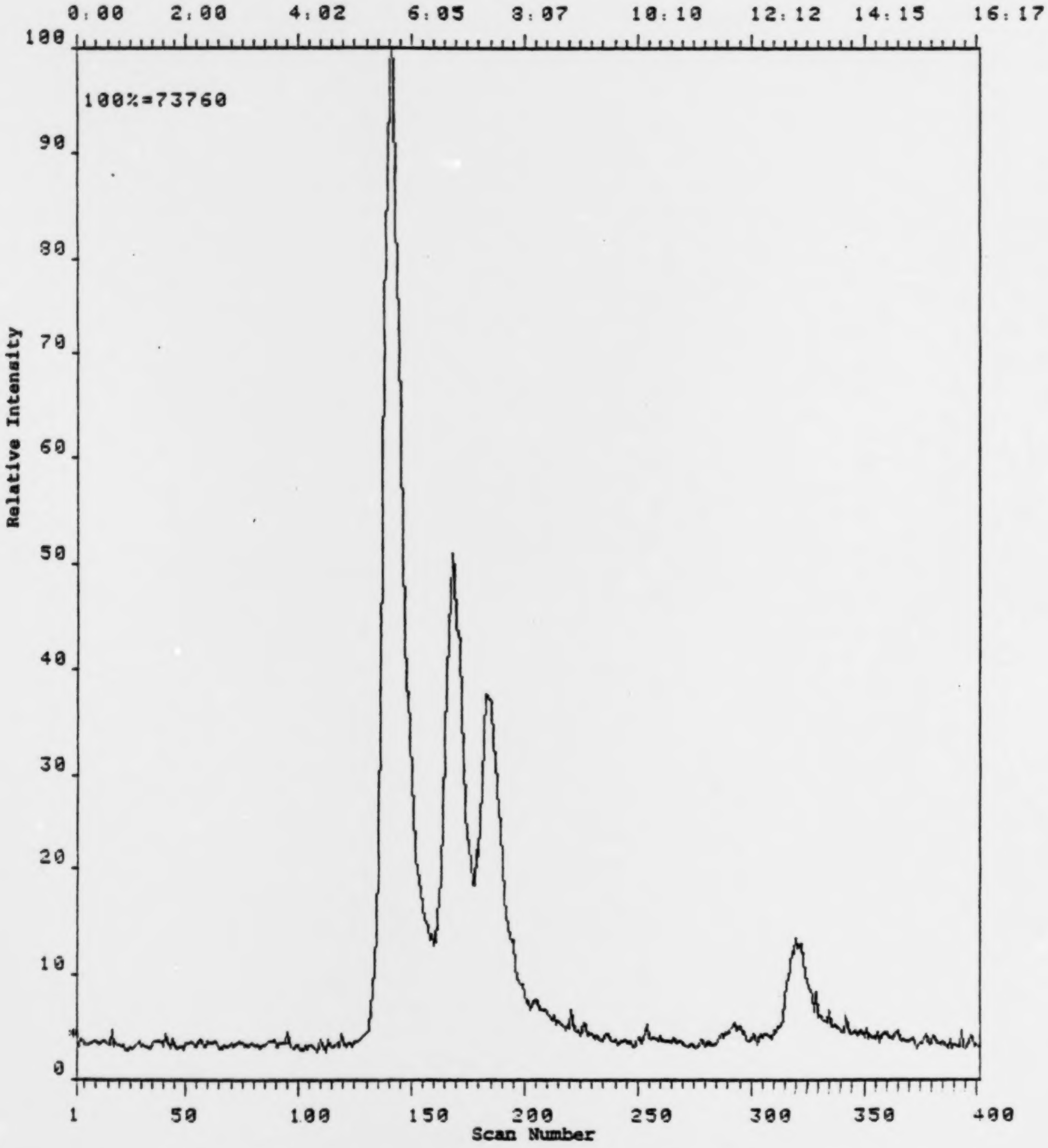

Figure 19. HRGC-LRMS Mass Chromatogram Obtained In Analysis of HpCDFs In Rollins Test 2, Train 1 Probe Wash Sample (TRW Number 6-0606).

DS-55 CROSS SCAN REPORT, RUN: RESDFF0002

* 423-426 # 431-432

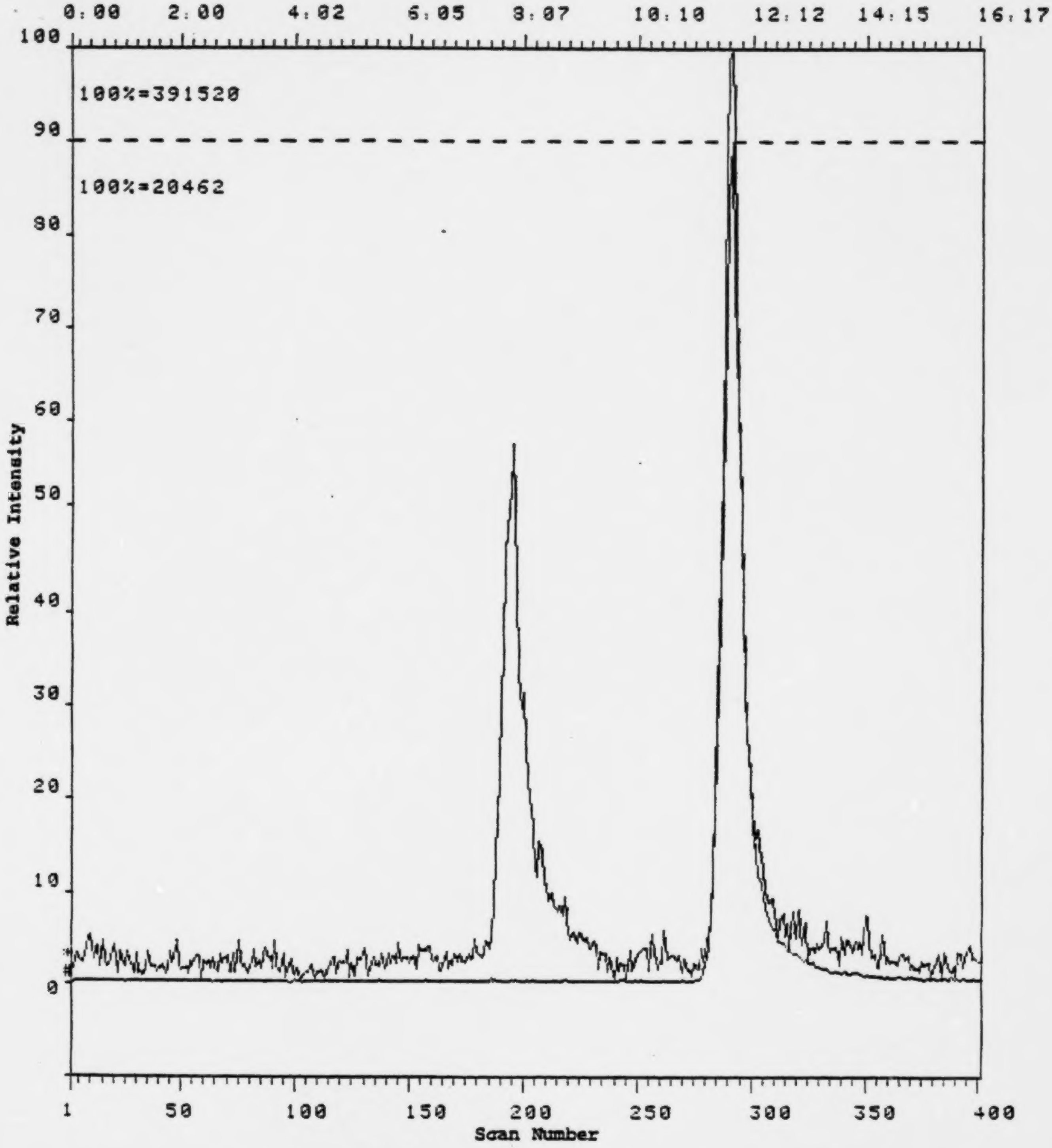

Figure 20. HRGC-LRMS Mass Chromatogram Obtained In Analysis of HpCDDs In Rollins Test 2, Train 1 Probe Wash Sample (TRW Number 6-0606).

DS-55 CROSS SCAN REPORT, RUN: RESDFG0002

* 441-444

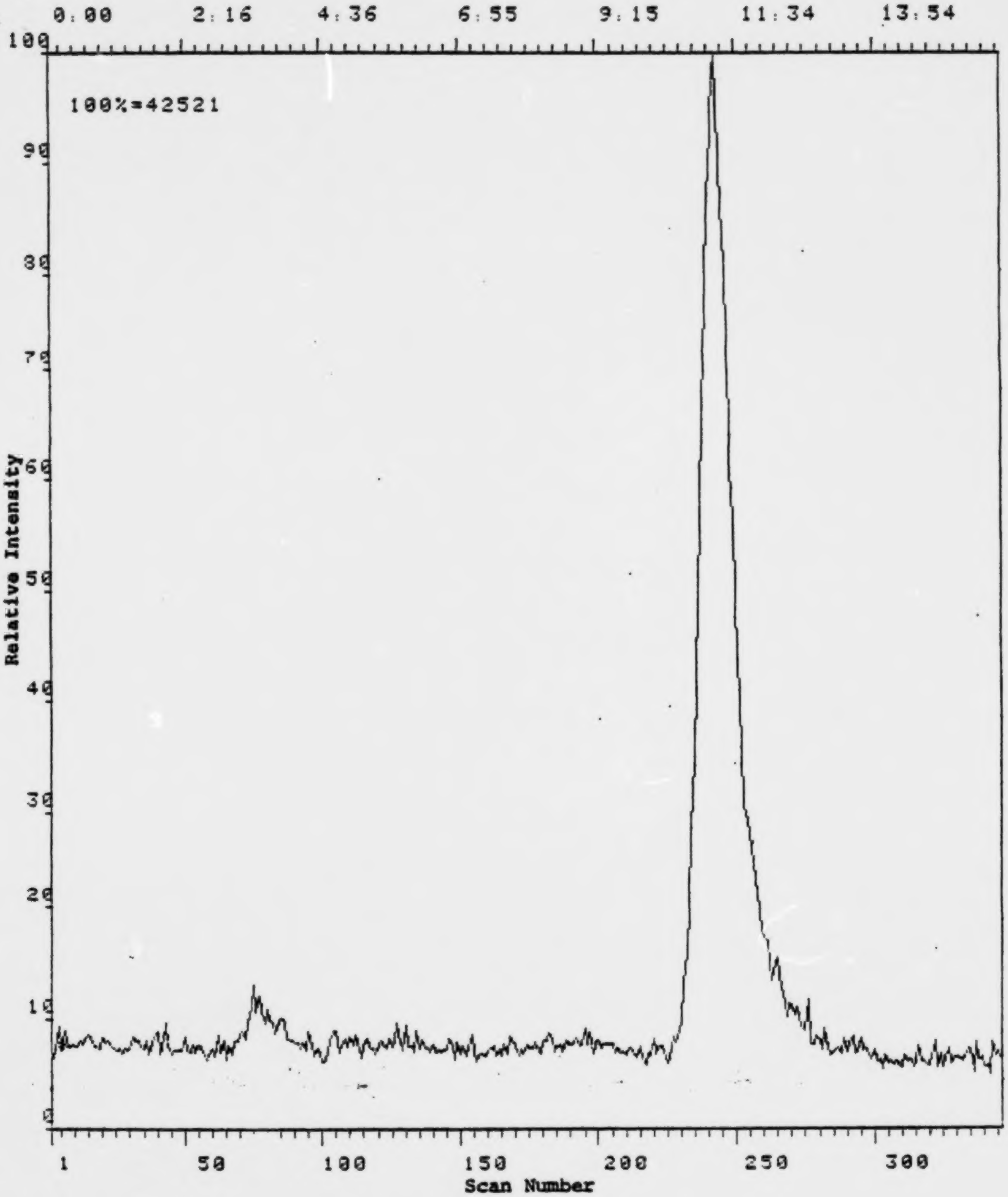

Figure 21. HRGC-LRMS Mass Chromatogram Obtained In Analysis Of OCDF In Rollins Test 2, Train 1 Probe Wash Sample (TRW Number 6-0606).

DS-55 CROSS SCAN REPORT, RUN: RESDFG0602

* 457-460

495

OCDD

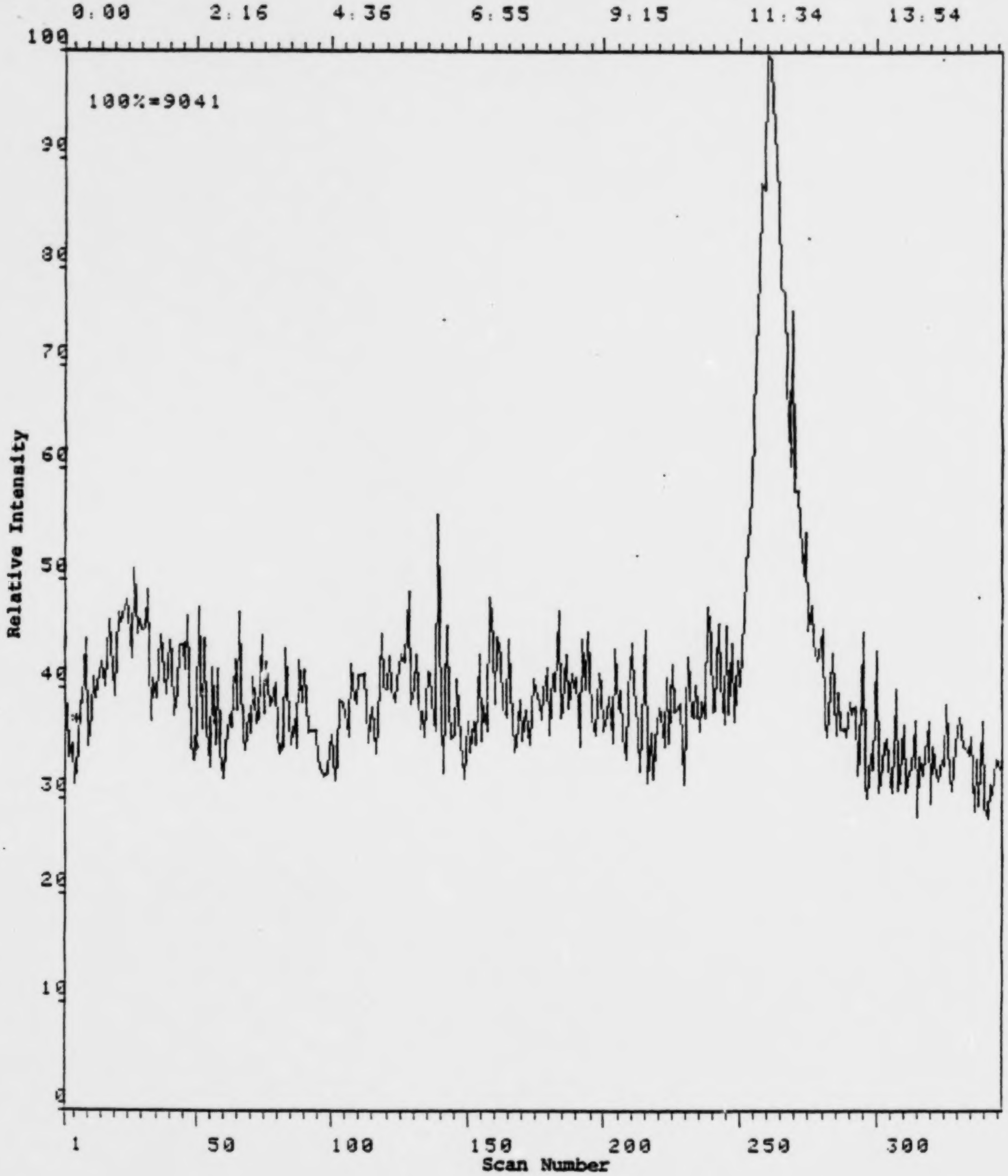

Figure 22. HRGC-LRMS Mass Chromatogram Obtained In Analysis of OCDD In Rollins Test 2, Train 1 Probe Wash Sample (TRW Number 6-0606).

496

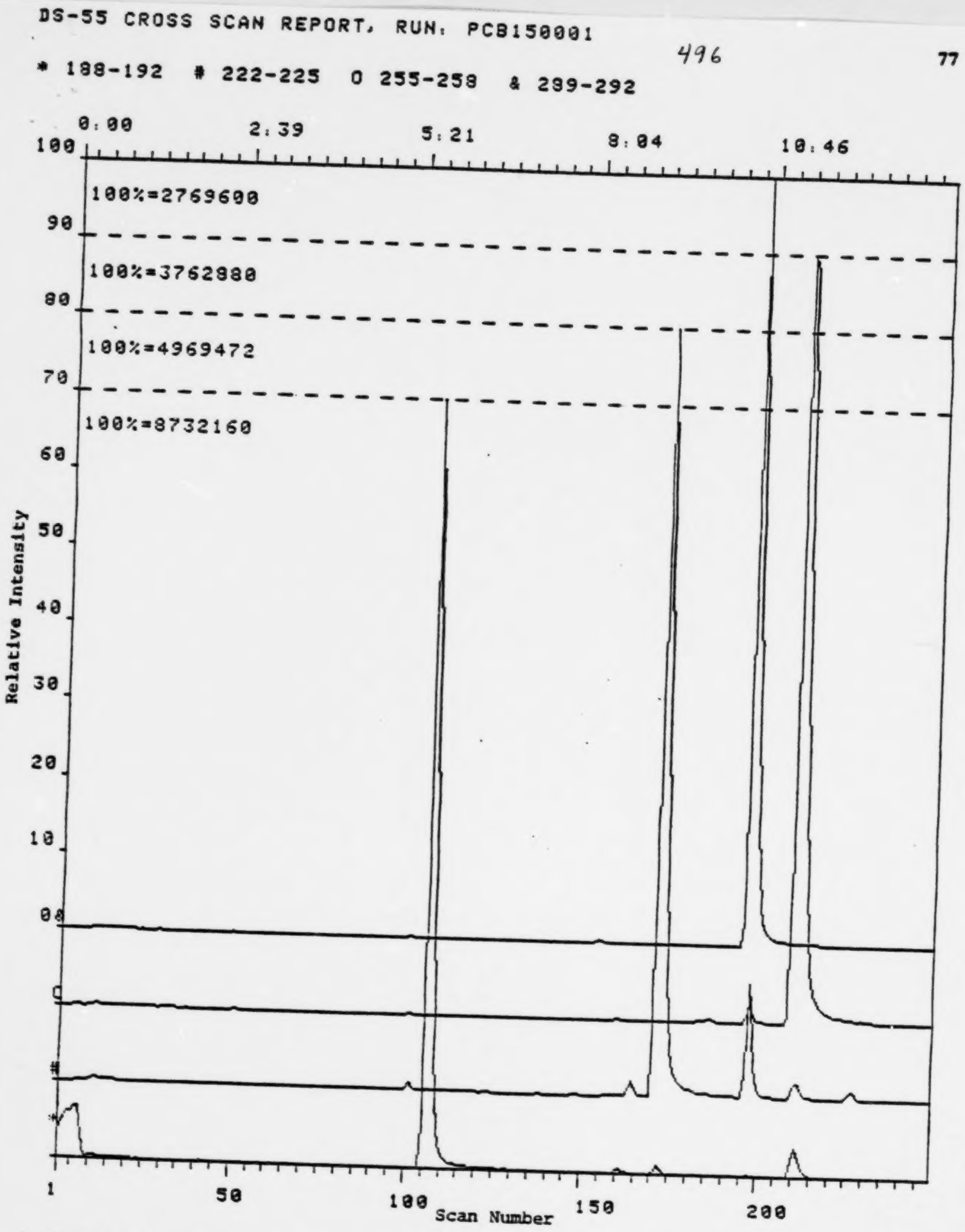

Figure 23. Selected Ion Mass Chromatograms Obtained From HRGC-LRMS Analysis Of a Mixture of Mono-, Di-, Tri- and Tetrachlorinated PCB Standards. Ions Monitored and Corresponding Symbols Used To Label Traces Are Listed At Top. See Table 6 For Listing of ion Masses Corresponding To Each PCB Class.

497

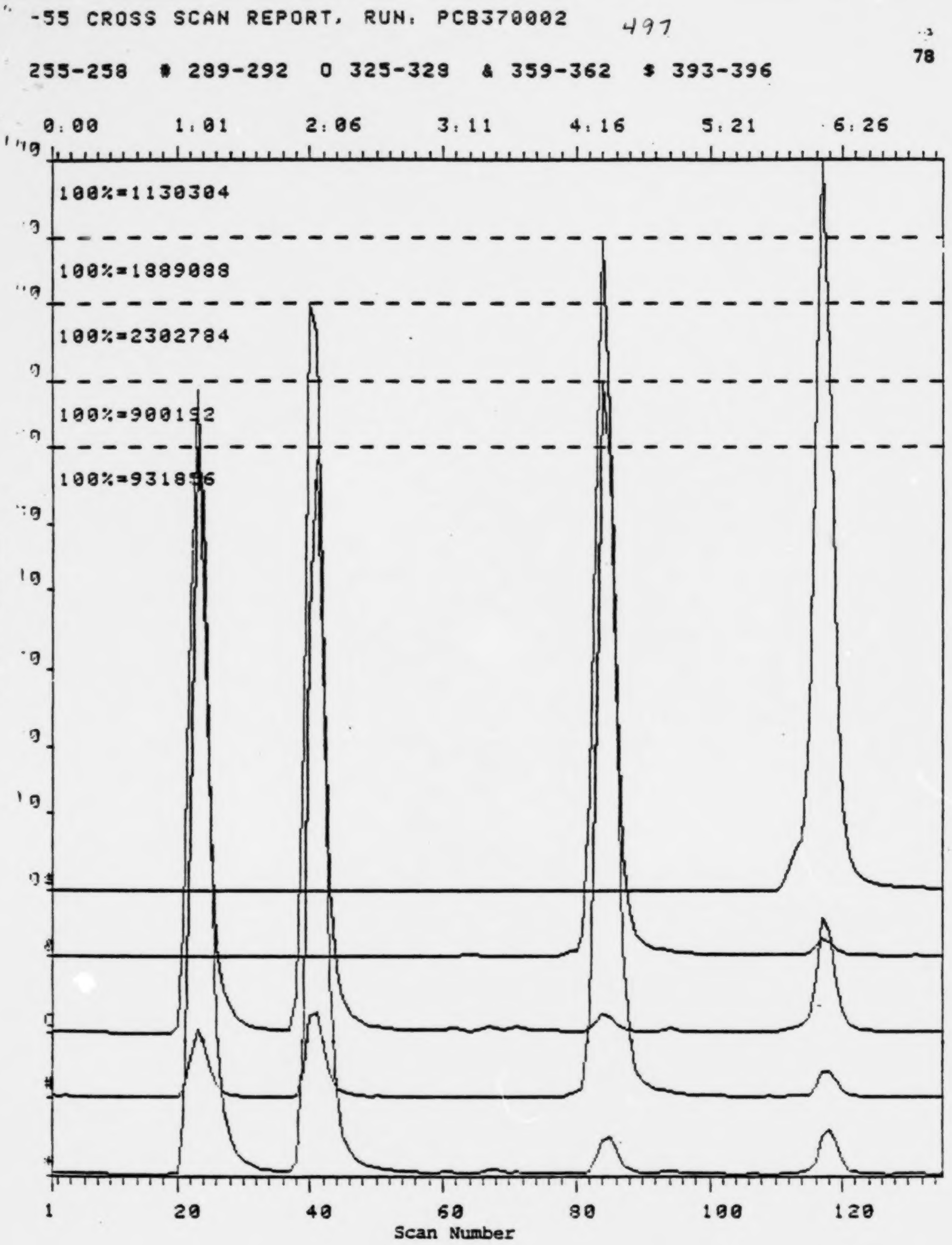

Figure 24. Selected-Ion Mass Chromatograms Obtained From HRGC-LRMS Analysis Of a Mixture of Tri-, Tetra-, Penta-, Hexa-, and Heptachlorinated PCB Standards.

498

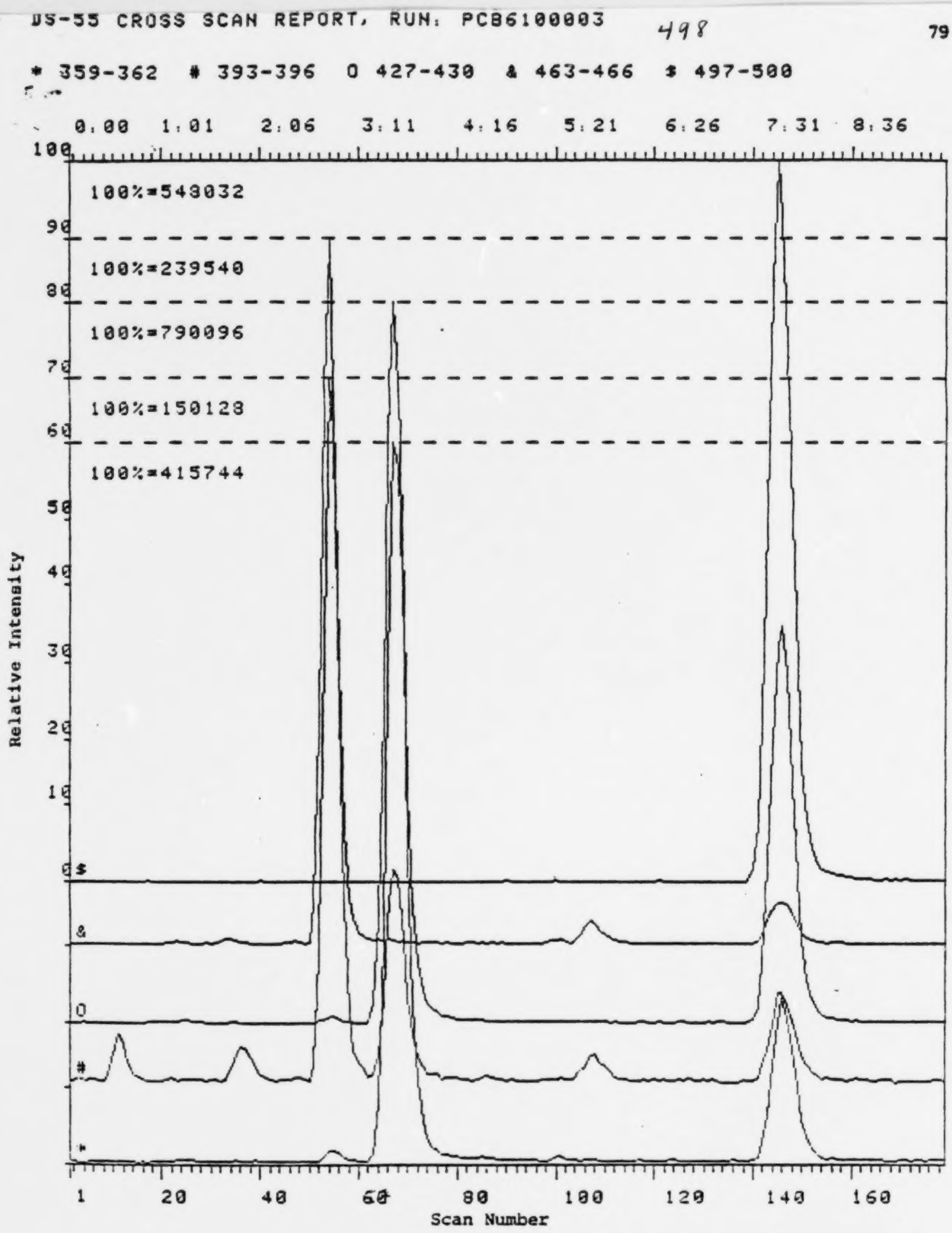

Figure 25. Selected Ion Mass Chromatograms Obtained From HRGC-LRMS Analysis Of a Mixture of Hexa-, Hepta-, Octa-, Nona-, and Decachlorinated PCB Standards.

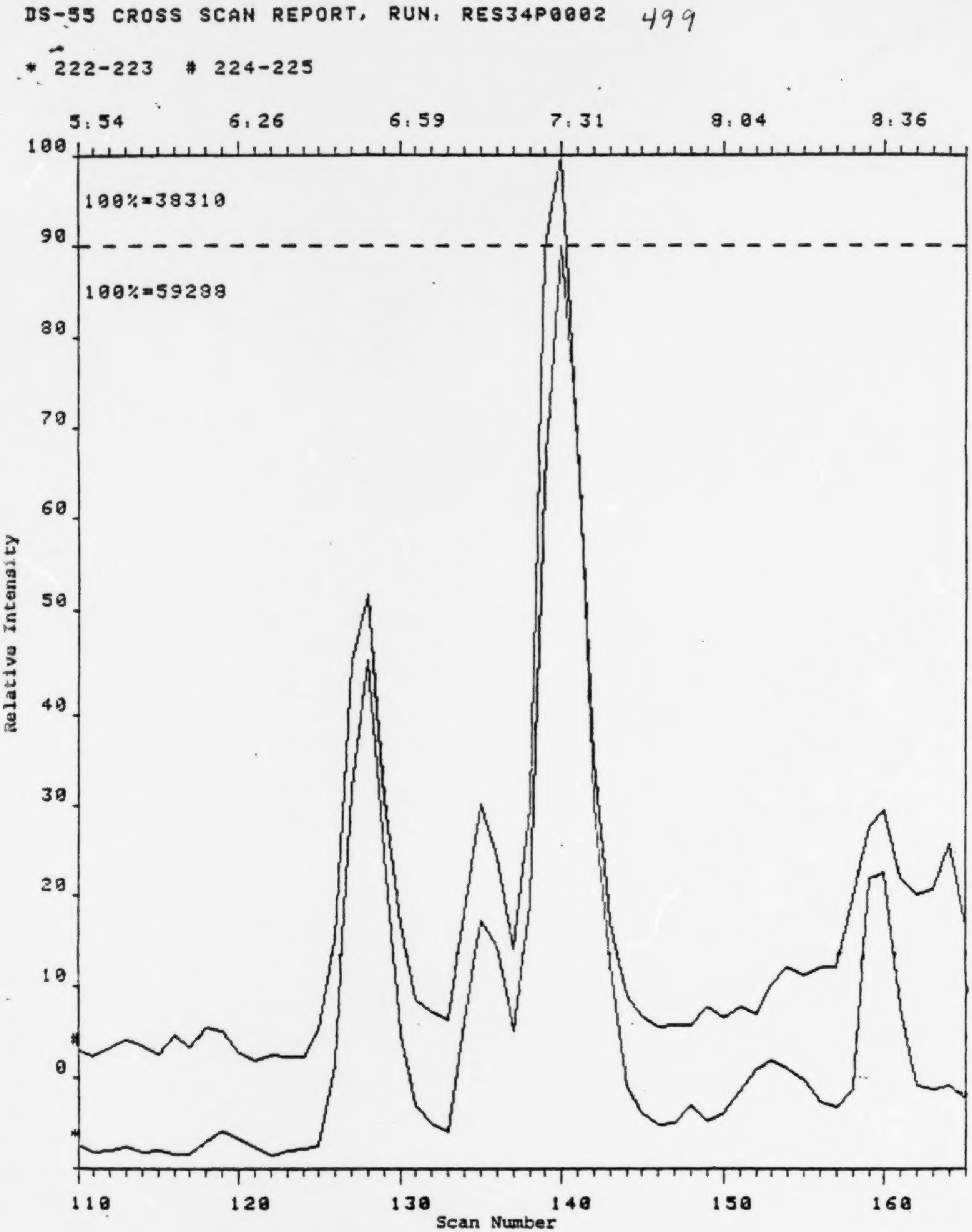

Figure 26. Selected Ion Mass Chromatograms Obtained From HRGC-LRMS Analysis Of ENSCO Test 2, Train 1 Florisil Sample (TRW 6-0609) For Dichlorinated PCBs.

500

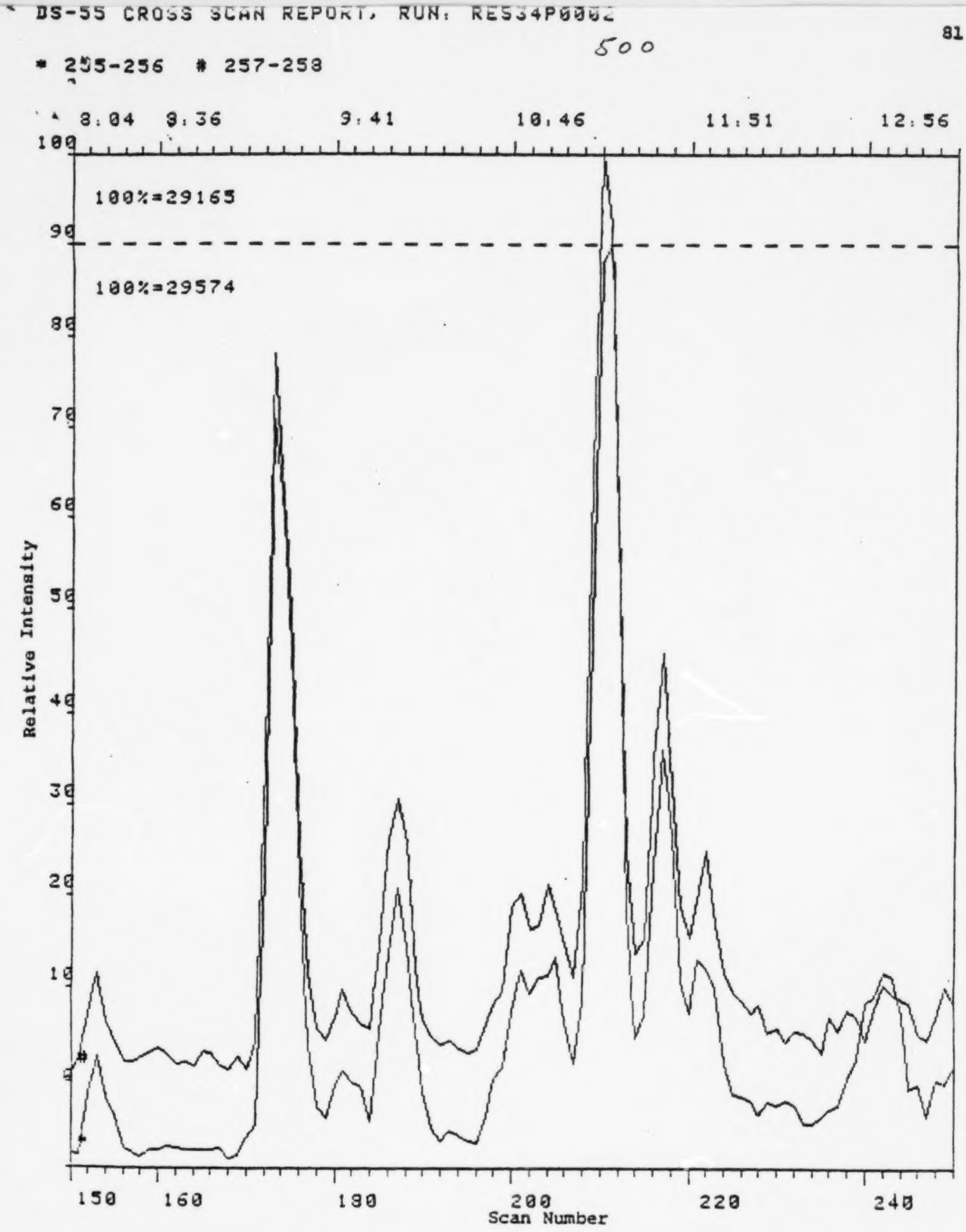

Figure 27. Selected Ion Mass Chromatograms Obtained From HRGC-LRMS Analysis of ENSCO Test 2, Train 1 Florisil Sample (TRW 6-0609) For Trichlorinated PCBs.

501

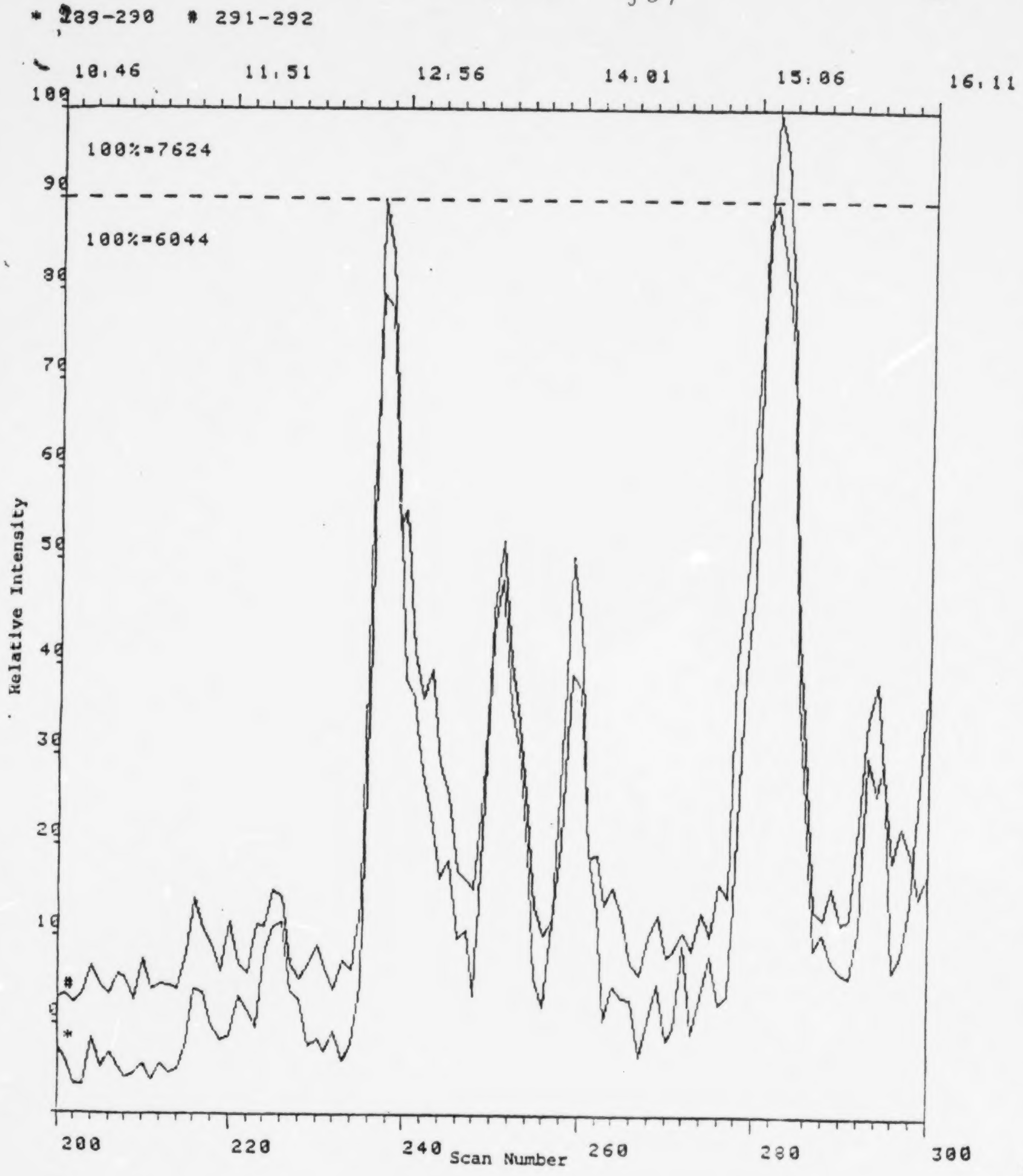

Figure 28. Selected Ion Mass Chromatograms Obtained From HRGC-LRMS Analysis of ENSCO Test 2, Train 1 Florisil Sample (TRW 6-0609) For Tetrachlorinated PCBs.

# Division 6

503

# Air Quality Modeling Analysis of Dioxin and Furan Emissions from Rollins

Prepared by: Joe Winkler
Air Programs Branch
EPA Region 6
January 1981

## I. Statement of Assignment

The task entails the evaluation of the ambient impact of dioxin and furan emission from Rollins. The following requirements were specified for the concentration estimates:

1. One year of National Weather Service meteorological data was used in the analysis.
2. Two concentration estimates were requested:
    a. Maximum annual concentration
    b. Maximum annual residential concentration
3. Model input assumptions
    a. Dioxins and furans behave as nonreactive gases and have infinite half-lifes
    b. The average stack gas velocity (10.97 m/sec) and stack gas temperature (345.0 K), based on tests for Day 1, Day 2, and Day 3 were used as representative of annual average values
    c. The emission rates identified in Table 1 were used as representative of annual average values.

## II. Selection of Modeling Technique

A dispersion model is a commonly used technique for relating pollutant emissions to ambient air quality. It is a mathematical description of pollutant transport, dispersion and transformation processes that occur in the atmosphere.

The current EPA guidance on selection and use of air quality models states that the gaussian plume model is state-of-the-art and recommended for pollutants that are nonreactive. The gaussian plume equation is a solution to the simplified conservation of mass equation.

The Rollins plant has one stack which is located on a site for which urban diffusion modeling parameters and urban mixing height assumptions were determined to be appropriate. This decision was based on using the land use procedure recommended in the proposed revisions to EPA's "Guideline on Air Quality Models" (Reference 2) and aerial photographs of the area around the stack.

Annual average concentrations are desired. The use of RAM (Gaussian - Plume Multiple-Source Air Quality Algorithm) in the long-term single point source mode is recommended in an urban area where there are no significant meteorological or terrain complexities. RAM is used to calculate concentrations for an entire year. The model output shows the annual arithmetic mean concentration at each of the receptor points of a radial grid and identifies the maximum annual concentration.

Consistent with the most recent EPA modeling guidance, the new version of RAM (12-80) was employed. Adequate verification of the new version was performed in the later part of 1980 by EPA's Office of Research and Development.

The basic time increment for the model is one hour. One-hour concentrations are computed for each of the hours in a given year. The one-hour values are averaged to obtain concentrations for longer averaging times.

Successful application of RAM is dependent on recognition of limitations imposed by mathematical assumptions associated with the model, the structure of the computer program, and the availability and form of meteorological data.

The assumptions incorporated into RAM can be summarized as follows:

1. The pollutant exhibits the dispersion behavior of a non-reactive gas.
2. Gravitational effects and chemical transformation of the pollutant are not considered.
3. Transformations of a pollutant resulting in its loss throughout the entire depth of each plume is accomplished by an exponential decrease with travel time from the source. The input parameter is the length of time expected for loss of 50% (half-life) of the emitted pollutant. Although this view of chemical or physical depletion processes is overly simplistic, it may be useful under certain circumstances.
4. Complete reflection of the plume takes place at the earth's surface, and the plume is completely reflected at the mixing height.
5. No consideration is given to the cumulative effects from consecutive 1-hour periods, and no allowance is made for changes in the wind with time to affect the path taken by the plume downwind.
6. No initial concentration of pollutant.
7. Continuous uniform emission rate.
8. Homogeneous horizontal wind field.
9. No directional wind shear in the vertical.
10. Dispersion coefficients are based on aerometric measurements taken in open, level to gently rolling terrain.
11. The pollutant within the plume takes on a gaussian distribution in both the horizontal crosswind and vertical directions. Dilution dominates diffusion in the downwind direction.

13. No consideration of aerodynamic effects resulting from the interaction of the wind with the physical structures nearby the plant.

14. The input wind direction includes a random variation (-4 to +5°) superimposed on the value recorded by the National Weather Service (NWS).

15. The wind speeds and directions should be hourly averages which are representative of the region being modeled. (In reality, NWS hourly observations are not hourly averages but are one minute averages at the time of observation, usually about 5 minutes before the hour).

16. A single mixing height and a single stability class for each hour are assumed representative of the area.

Please refer to the RAM Users' Manual (Reference 1) for a more complete and thorough treatment of RAM assumptions and limitations.

RAM presents a specific set of input data requirements, and yields output data consisting of pollutant concentrations for a specific averaging time and receptor locations. The input data requirements can be broadly classified as meteorological factors, source factors and site factors.

As specified in the "Statement of Assignment," only one year of meteorological data (1964) was used in the RAM Modeling. In view of the priority placed on the modeling effort, the decision was made to use one year of Houston (Hobby) surface data and one year of Lake Charles, Louisiana upper air data (for mixing heights) as being the most representative data readily available. Meteorological inputs to the model consisted of the following observations from each day of 1964:

1. hourly wind speed
2. hourly wind direction sector (tens of degrees)
3. hourly ambient air temperature
4. hourly total opaque cloud cover
5. twice daily mixing heights
6. hourly cloud ceiling height

The source data required for calculation of an annual average concentration consists of an annual average emission rate, annual average stack gas exit velocity and annual average stack gas temperature. (See Attachment 1.) In addition, the following emission source parameters were input into RAM:

1. Plant elevation and locations
2. Stack exit diameter
3. Physical stack height

A description of the site and its surroundings is provided in Attachment 2. RAM has available a radial receptor grid. This grid provides for receptors at five different distances on thirty-six (10° increment) radials or a total of 180 receptors for each model run. Based on model test runs, a dense receptor grid near the absolute maxima and a line of grid points along the southern boundary of the residential area to the north and north northwest were employed.

## III. Model Application

The latest EPA modeling guidance recommends that the following options and parameters be applied to the RAM Modeling:

1. The urban option was employed.
2. Terrain in the area modeled was assumed to be flat.
3. Infinite half-life was assumed.
4. Stack tip downwash was not used.
5. Final plume rise was used rather than transitional plume rise.
6. Buoyancy induced dispersion was not used. (As stated in Reference 3, buoyancy induced dispersion should only be used with complex terrain models).
7. The anemometer height was assumed to be at 10 meters.
8. The following urban wind profile law exponents were used: For stability A: 0.15, B: 0.15, C: 0.20, D: 0.25, E: 0.40, F: 0.60. (See page 13 of Reference 1.)
9. 1964 Houston (Hobby) surface data was used.
10. 1964 Lake Charles upper air data was used.
11. Receptors were placed along each of 36 radials originating at the stack location at the intersections of the following ring distances (km): 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 3.2, and 4.5. In order to locate the absolute maximum, a dense receptor network was placed close to the point source around the 340° radial.

The following emission source parameters were used in this RAM modeling:

1. Stack base elevation: 0 feet.
2. Stack location (long/lat): 95° 05' 45"/29° 43' 45" (Texas Control Board Permit)
3. Annual average stack gas exit velocity: 10.97 m/sec.
4. Annual average stack gas temperature: 345.0 K.

5. Physical Stack Height: 30.48 m.

6. Stack Exit Diameter: 1.83 m.

7. Annual Average Emission Rates: (See Table 1.)

## IV. Consideration of Background

The contributions due to background were not considered in the air quality analysis.

## V. Presentation of Results

The results are presented in Table 1. When evaluating these results it is important to consider the assumptions incorporated into RAM which were discussed above. In particular, the dispersion coefficients are valid only for downwind distances greater than 100 meters from the stack. Beyond a few kilometers downwind, the estimates are based on limited data and so may be less accurate. It should be remembered in this application of RAM that the accuracy of the results is dependent upon not only the model, but on the quality of the input information used in the application (including both emission information and meteorological data).

## VI. Acknowledgements

The author wishes to recognize the major contributions of F. Hall and J. Yarbrough to this study. F. Hall's preliminary work and prudent advice were invaluable. Special recognition is due to J. Yarbrough who did the bulk of the computer modeling. The author also wishes to thank L. Stevens, J. Sales and P. Schwindt for their contributions.

## VII. References

1. User's Guide for RAM, November 1978, (EPA-600/8-78-016A).

2. Proposed Revisions to "Guideline on Air Quality Models," October 1980.

3. DRAFT Regional Workshops on Air Quality Modeling: A Summary Report, July 1980.

# Table I

| Test Day | Annual Average Emission Rates | Absolute Maximum Annual Concentrations (grams/meter$^3$)*/ Distance and Direction from Stack | Maximum Annual Concentrations (grams/meter$^3$)* in the Residential Area/Distance and Direction from the Stack |
|---|---|---|---|
| | TCDD (1x10$^{-9}$ grams/second) | | |
| | 1. Adding in detection limits for ND samples | | |
| Day 1 | 43.74 | 4.68x10$^{-14}$/0.24 km N, 0.8 km W | 2.19x10$^{-15}$/4.3 km N, 1.2 km W |
| Day 2 | 17.83 | 1.91x10$^{-14}$/0.24 km N, 0.8 km W | 8.92x10$^{-16}$/4.3 km N, 1.2 km W |
| Day 3 | 9.64 | 1.03x10$^{-14}$/0.24 km N, 0.8 km W | 4.82x10$^{-16}$/4.3 km N, 1.2 km W |
| | 2. Without detection limits | | |
| Day 1 | 43.74 | 4.68x10$^{-14}$/0.24 km N, 0.8 km W | 2.19x10$^{-15}$/4.3 km N, 1.2 km W |
| Day 2 | 10.34 | 1.11x10$^{-14}$/0.24 km N, 0.8 km W | 5.17x10$^{-16}$/4.3 km N, 1.2 km W |
| Day 3 | 9.64 | 1.03x10$^{-14}$/0.24 km N, 0.8 km W | 4.82x10$^{-16}$/4.3 km N, 1.2 km W |
| | TCDF (1x10$^{-9}$ grams/second) | | |
| | 1. Adding in detection limits for ND samples | | |
| Day 1 | 90.13 | 9.64x10$^{-14}$/0.24 km N, 0.8 km W | 4.51x10$^{-15}$/4.3 km N, 1.2 km W |
| Day 2 | 166.67 | 1.78x10$^{-13}$/0.24 km N, 0.8 km W | 8.33x10$^{-15}$/4.3 km N, 1.2 km W |
| Day 3 | 19.28 | 2.06x10$^{-14}$/0.24 km N, 0.8 km W | 9.64x10$^{-16}$/4.3 km N, 1.2 km W |
| | 2. Without detection limits | | |
| Day 1 | 85.08 | 9.10x10$^{-14}$/0.24 km N, 0.8 km W | 4.25x10$^{-15}$/4.3 km N, 1.2 km W |
| Day 2 | 160.13 | 1.71x10$^{-13}$/0.24 km N, 0.8 km W | 8.01x10$^{-15}$/4.3 km N, 1.2 km W |
| Day 3 | 12.44 | 1.33x10$^{-14}$/0.24 km N, 0.8 km W | 6.22x10$^{-16}$/4.3 km N, 1.2 km W |

*These are annual arithmetic averages

## Attachment 1

## Sampling and Analysis for PCBs, Dioxins, and Furans

In order to determine the emission rates of the various air pollutants, EPA required the facilities to conduct stack emission tests. Tests were conducted by an independent testing firm using methods and procedures prescribed by EPA.

During all emission tests, EPA representatives were on-site observing the tests and recording information concerning the operation of the incinerator and the air pollution control equipment.

Sampling for PCBs, dioxins and furans was performed in the stack utilizing a modified EPA Method 5 sampling train. The sampling train incorporated two (2) resin cartridges to adsorb the organic vapors. The resin cartridges contained XAD-2 resin and florisil resin.

The resin cartridges were located downstream from the probe and between the third and fourth impingers. The sampling train was designed to collect both particulates and organic compounds in the stack gas. Both resins were used so that the second resin would absorb any residual organic compounds which may have passed through the first resin. For dioxin and furans, the cartridges which house the resins were water jacketed. Cold water from the ice bath surrounding the impingers was pumped into the jackets which maintained the resins at a temperature of less than 70°F. Because of the sensitivity of organic compounds to ultraviolet light, the resin cartridges, impingers, and interconnecting glassware were protected from the sunlight by aluminum foil and opaque plastic.

The stack gases were sampled isokinetically for a period of four hours. At the completion of each sampling period, the stack samples were transported to the laboratory for analysis. The stack samples were extracted with an appropriate solvent and analyzed using capillary column gas chromatography and high resolution mass spectrometry. For dioxins and furans, and added quality control technique was used. The stack samples were spiked with a labeled dioxin and furan which allowed the analyst to determine the extraction efficiency of each sample.

## Attachment 2

## Rollins at Deer Park, Texas

### Surroundings

The Rollins Environmental Services facility is located on the south side of the Houston Ship Channel, about 4,000 feet to the southwest of the shoreline. It is in the middle of one of the most densely industrialized areas in the nation. From the Ship Channel's Turning Basin at the edge of downtown Houston, to the Bayport Bridge, the ship channel is lined on both sides with industrial complexes. Because of the complete lack of zoning regulations in the area, these industrial districts are closely flanked by residential neighborhoods and small incorporated townships. Within the area of concern for emissions from Rollins there are two townships: Deer Park and Deepwater. These are located to the south and southwest of the Rollins plant site, with the most populous portions of both towns lying within three miles of the site.

The ecological character of the region is that of a coastal short-grass prairie. There are no known characteristics of the flora or fauna which would make them especially susceptible to or immune from contamination by dioxins or furans.

### Distribution of Population

The Agency estimates that up to 25,000 people could experience exposure to some level of emissions from the incinerator. Within a radius of one-mile the only exposed population is a group of employees of the nearby industries. These would be subject to an eight-hour exposure. Within a two-mile radius is the most densely populated center of Deer Park. A three-mile radius takes in about 1/3 of the most densely populated section of the town of Deepwater.

# Division 7

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# Air Quality Modeling Analysis of Dioxin and Furan Emissions from ENSCO

Prepared by: Joe Winkler
Air Programs Branch
EPA Region 6
January 1981

ENSCO

## I. Statement of Assignment

The task entails the evaluation of the ambient impact of dioxin and furan emissions from ENSCO. The following requirements were specified for the concentration estimates:

1. One year of National Weather Service meteorological data was used in the analysis.

2. Two concentration estimates were requested:

   a. Maximum annual concentration.

   b. Maximum annual residential concentration.

3. Model input assumptions:

   a. Dioxins and furans behave as nonreactive gases and have infinite half-lifes.

   b. The average stack gas velocity (2.86 m/sec) and stack gas temperature (346.6 K), based on tests for Day 1, Day 2, and Day 3, were used as representative of annual average values.

   c. The emission rates identified in Table 1 were used as representative of annual average values.

## II. Selection of Modeling Technique

A dispersion model is a commonly used technique for relating pollutant emissions to ambient air quality. It is a mathematical description of pollutant transport, dispersion and transformation processes that occur in the atmosphere.

The current EPA guidance on selection and use of air quality models states that the gaussian plume model is state-of-the-art and recommended for pollutants that are nonreactive. The gaussian plume equation is a solution to the simplified conservation of mass equation.

The ENSCO plant has one stack which is located on a site for which rural diffusion parameters and rural mixing height assumptions were determined to be appropriate. This decision was based on using the land use procedure recommended in the proposed revisions to EPA's "Guideline on Air Quality Models" (Reference 2) and aerial photographs of the area around the stack.

Annual average concentrations are desired. The Single Source (CRSTER) Model is recommended for point source applications in rural areas where there is one stack and there are no significant meteorological or terrain complexities. The CRSTER model calculates concentrations for an entire year and prints out the annual arithmetic mean concentration at each of the receptor points of a radial grid and lists the maximum annual concentration.

The CRSTER model is based on a modified form of the gaussian plume equation which uses empirical dispersion coefficients and includes adjustments for plume rise, limited mixing height and elevated terrain. The basic time increment for the model is one hour. One hour concentrations are computed for each of the hours in a given year. The 1-hour values are averaged to obtain concentrations for longer averaging times.

Successful application of the CRSTER model is dependent on recognition of limitations imposed by mathematical assumptions associated with the model, the structure of the computer program, and the availability and form of source data and meteorological data.

The assumptions incorporated into the CRSTER model can be summarized as follows:

1. The pollutant exhibits the dispersion behavior of a non-reactive gas.
2. Gravitational effects and chemical transformation of the pollutant are not considered.
3. None of the pollutant is removed from the plume (by, e.g., rainout, washout and dry deposition) as the plume advects and diffuses downwind.
4. Complete reflection of the plume takes place at the earth's surface, and the plume is completely reflected at the mixing height.
5. No consideration is given to the cumulative effects from consecutive 1-hour periods, and no allowance is made for changes in the wind with time to affect the path taken by the plume downwind.
6. No initial concentration of pollutant.
7. Continuous uniform emission rate.
8. Homogeneous horizontal wind field.
9. No directional wind shear in the vertical.
10. Dispersion coefficients are based on aerometric measurements taken in open level to gently rolling terrain.
11. The pollutant within the plume takes on a gaussian distribution in both the horizontal crosswind and vertical directions. Dilution dominates diffusion in the downwind direction.
12. Constant eddy diffusivities.

13. No consideration of aerodynamic effects resulting from the interaction of the wind with the physical structures nearby the plant.

14. The input wind direction includes a random variation (-4 to +5°) superimposed on the value recorded by the National Weather Service (NWS).

15. The wind speeds and directions should be hourly averages which are representative of the region being modeled. (In reality, NWS hourly observations are not hourly averages but are one minute averages at the time of observation, usually about 5 minutes before the hour).

16. A single mixing height and a single stability class for each hour are assumed representative of the area.

Please refer to the CRSTER Users' Manual (Reference 1) for a more complete and thorough treatment of the CRSTER model assumptions and limitations.

The CRSTER model presents a specific set of input data requirements, and yields output data consisting of pollutant concentrations for a specific averaging time and receptor location. The input data requirements can be broadly classified as meteorological factors, source factors and site factors.

As specified in the "Statement of Assignment," only one year of meteorological data (1964) was used in the CRSTER Modeling. Shreveport, Louisiana was selected as the most representative location for which one year of meteorological data was immediately available. Meteorological inputs to the model consisted of the following observations from each day of 1964:

1. hourly wind speed
2. hourly wind direction sector (tens of degrees)
3. hourly ambient air temperature
4. hourly total opaque cloud cover
5. twice daily mixing heights
6. hourly cloud ceiling height

The source data required for calculation of an annual average concentration consists of an annual average emission rate, annual average stack gas exit velocity and annual average stack gas temperature. (See Attachment 1). In addition the following emission source parameters were input into the CRSTER model:

1. Plant elevation and location
2. Stack exit diameter
3. Physical stack height

A description of the site and surroundings is provided in Attachment 2. The effect of terrain was taken into account. The CRSTER model includes a terrain adjustment procedure to simulate the effect of elevated terrain.

For a receptor location above the base elevation of the stack, but below the effective plume height of the stack, the plume centerline is lowered. In other words, the terrain adjustment procedure decreases the effective plume height by an amount equal to the difference in elevation between the plant site and the specific receptor site. The model then uses the adjusted plume height in estimating concentrations at the receptor. Also the model considers receptors below base elevation of the stack to be at base elevation.

CRSTER has available a radial receptor grid. This grid provides for receptors at five different distances on thirty-six (10° increment) radials or a total of 180 receptors for each model run. Attachment 3 provides an explanation on how the terrain heights for the receptors were determined.

## III. Model Application

The latest EPA modeling guidance recommends that the techniques used in the CRSTER model, specifically those included in the model's default options, should generally be used for rural applications. The following options and parameters were employed in the CRSTER modeling for ENSCO's air quality impact analysis:

1. Final plume rise was used rather than transitional plume rise.
2. The anemometer height was assumed to be at 7 meters.
3. Stack tip downwash was not accounted for.
4. The default set of wind profile law exponents were used.
5. The emissions were assumed to originate from a hot, bouyant stack plume.
6. The rural option was selected.
7. 1964 surface Shreveport data was used.
8. 1964 upper air Shreveport data was used.
9. Terrain receptors were used. Receptors were placed along 36 radials originating at the stack location at the intersections of the following ring distances (km), 0.4, 0.5, 0.55, 0.6, 0.65, 0.7, 0.8, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, and 1.7.

The following emission source parameters were used in this CRSTER modeling:

1. Stack base elevation: 244 feet
2. Stack location: Longitude 92°37'48"
   Latitude 33°12'17"

3. Annual stack gas exit velocity: 2.86 m/sec
4. Annual average stack gas temperature: 346.6K
5. Physical Stack Height: 60.96 m
6. Stack Exit Diameter: 2.83 m
7. Annual Average Emission Rates: (See Table 1)

## IV. Consideration of Background

The contributions due to background were not considered in the air quality analysis.

## V. Presentation of Results

The results are presented in Table 1. When evaluating these results it is important to consider the assumptions incorporated into the CRSTER model which were discussed above. In particular, the dispersion coefficients are valid only for downwind distances greater than 100 meters from the stack. Beyond a few kilometers downwind, the estimates are based on limited data and so may be less accurate.

As reported in Reference 3, validation studies of the CRSTER model were performed for five power plants. Until further studies become available, it may be concluded from these validation studies for power plants that the CRSTER model is generally accurate within a factor of two. It should be remembered in this application of CRSTER that the accuracy of the results is dependent upon not only the model, but on the quality of the input information used in the application (including both emission information and meteorological data).

## VI. Acknowledgements

The author wishes to recognize the major contributions of F. Hall and J. Yarbrough to this study. F. Hall's preliminary work and prudent advice were invaluable. Special recognition is due to J. Yarbrough who did the bulk of the computer modeling. The author is grateful to D. Speak who provided the terrain elevations. The author also wishes to thank L. Stevens, J. Sales, and P. Schwindt for their contributions.

## VII. References

1. Users Manual for Single-Source (CRSTER) Model, July 1977 (EPA-450/2-77-013)

2. Proposed Revisions to "Guidelines on Air Quality Models," October 1980

3. Applications of the Single Source (CRSTER) Model to Power Plants: A Summary, J. A. Tikvart and C. E. Mears, Proceedings of the Conference on Environmental Modeling and Simulation, July 1976

4. Validation of a Single Source Dispersion Model, Russell F. Lee and Michael T. Mills, Proceedings of the Sixth International Technical Meeting on Air Pollution Modeling and its Application MATO/CCMS, September 1975

## Table I

| Test Day | Annual Average Emission Rates | Absolute Maximum Annual Concentrations (grams/meter$^3$)*/ Distance and Direction from Stack | Maximum Annual Concentrations (grams/meter$^3$)* in the Residential Area/Distance and Direction from the Stack |
|---|---|---|---|
|  | TCDD ($1*10^{-9}$ grams/second) |  |  |
|  | 1. Adding in detection limits for ND samples |  |  |
| Day 1 | 1.46 | $2.09x10^{-16}$/1.2 km at $310^0$ *** | Same as absolute maximum ** |
| Day 2 | 6.26 | $8.95x10^{-16}$/1.2 km at $310^0$ | Same as absolute maximum ** |
| Day 3 | 5.26 | $7.52x10^{-16}$/1.2 km at $310^0$ | Same as absolute maximum ** |
|  | 2. Without detection limits |  |  |
| Day 1 | 0.95 | $1.36x10^{-16}$/1.2 km at $310^0$ | Same as absolute maximum ** |
| Day 2 | 1.69 | $2.42x10^{-16}$/1.2 km at $310^0$ | Same as absolute maximum ** |
| Day 3 | 5.26 | $7.52x10^{-16}$/1.2 km at $310^0$ | Same as absolute maximum ** |
|  | TCDF ($1*10^{-9}$ gram/second) |  |  |
|  | 1. Adding in detection limits for ND samples |  |  |
| Day 1 | 18.67 | $2.67x10^{-15}$/1.2 km at $310^0$ | Same as absolute maximum ** |
| Day 2 | 24.07 | $3.44x10^{-15}$/1.2 km at $310^0$ | Same as absolute maximum ** |
| Day 3 | 10.44 | $1.49x10^{-15}$/1.2 km at $310^0$ | Same as absolute maximum ** |
|  | 2. Without detection limits |  |  |
| Day 1 | 7.32 | $1.05x10^{-15}$/1.2 km at $310^0$ | Same as absolute maximum ** |
| Day 2 | 21.24 | $3.04x10^{-15}$/1.2 km at $310^0$ | Same as absolute maximum ** |
| Day 3 | 10.44 | $1.49x10^{-15}$/1.2 km at $310^0$ | Same as absolute maximum ** |

*These are annual arithmetic averages.

**The absolute maximum is located within a residential neighborhood. Therefore, the two maximum concentrations will be at one location.

***Where $360^0$ is due north of the stack.

## Attachment 1

## Sampling and Analysis for PCBs, Dioxins, and Furans

In order to determine the emission rates of the various air pollutants, EPA required the facilities to conduct stack emission tests. Tests were conducted by an independent testing firm using methods and procedures prescribed by EPA.

During all emission tests, EPA representatives were on-site observing the tests and recording information concerning the operation of the incinerator and the air pollution control equipment.

Sampling for PCBs, dioxins and furans was performed in the stack utilizing a modified EPA Method 5 sampling train. The sampling train incorporated two (2) resin cartridges to adsorb the organic vapors. The resin cartridges contained XAD-2 resin and florisil resin.

The resin cartridges were located downstream from the probe and between the third and fourth impingers. The sampling train was designed to collect both particulates and organic compounds in the stack gas. Both resins were used so that the second resin would absorb any residual organic compounds which may have passed through the first resin. For dioxin and furans, the cartridges which house the resins were water jacketed. Cold water from the ice bath surrounding the impingers was pumped into the jackets which maintained the resins at a temperature of less than 70°F. Because of the sensitivity of organic compounds to ultraviolet light, the resin cartridges, impingers, and interconnecting glassware were protected from the sunlight by aluminum foil and opaque plastic.

The stack gases were sampled isokinetically for a period of four hours. At the completion of each sampling period, the stack samples were transported to the laboratory for analysis. The stack samples were extracted with an appropriate solvent and analyzed using capillary column gas chromatography and high resolution mass spectrometry. For dioxins and furans, and added quality control technique was used. The stack samples were spiked with a labeled dioxin and furan which allowed the analyst to determine the extraction efficiency of each sample.

# Attachment 2

## ENSCO at El Dorado, Arkansas

### Surroundings

El Dorado, Arkansas is known as the capital of the petroleum and chemical industry in the State. This is a relative term, since the bulk of Arkansas is strictly rural in nature. Ninety percent of the area around El Dorado is forest.

The area presents a topography of gently rolling hills rising to an elevation of about 260 feet above sea level, with the intervening valleys at about 180 to 200 feet elevation. The ENSCO facility itself is located to the east of El Dorado in a small industrial park. There are several small communities, including churches and other public facilities, adjacent to the plant boundaries.

The surrounding forest is a mixture of deciduous and coniferous trees with typical upland animal species. There is a small area (3% of the total) of wetlands to the south. While the effects of chlorinated dibenzodioxins and furans on such environmental systems have not been studies in detail, the persistence and potential for bioaccumulation of these materials have been documented.

### Distribution of Population

The population of El Dorado is about 25,000. Another 24,000 people live within the maximum limits to which the air dispersion modeling of ENSCO's emissions was applied.

El Dorado has the fourth largest per capita income in Arkansas, with most of this coming from manufacturing, wholesale and retail sales, and services.

Attachment 3

# MAPPING GRID SUMMARY
# FOR THE ENSCO INCINERATOR
# AIR MODEL DEVELOPMENT

BY

DEBORAH K. SPEAK

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGIONAL ANALYTIC CENTER

DECEMBER 1980

## MAPPING ACCURACY

Maps used for plotting the 36 point grid for the application of the air model were accessed from the Department of Interior, United States Geological Survey (USGS). The USGS is in the process of processing and editing 7.5 minute quadrangles for the El Dorado area which was utilized in this mapping exercise. This map was then enlarged further for establishing the grid used in the model.

The National Standards for the horizontal and vertical accuracy of topographics maps were adopted in 1941. The standards for horizontal accuracy require that no more than 10 percent of the well-defined map points tested shall be more than 1/50 inch (0.5 mm) out of correct position at publication scales or 1:20,000 or smaller. This tolerance corresponds to 40 feet on the ground for the 1:24,000 scale map that was enlarged by a factor of 2. The standards for vertical accuracy requires that no more than 10 percent of the elevations of test points interpolated from contours be in error more than half the contour interval.

## MAPPING METHODS

The air model uses elevations from the surrounding El Dorado area, to predict concentrations expected from the incinerator stack emissions. The elevations are taken at 504 points. Elevation points are the intersections between circles drawn from around the stack and 36 lines at 10 degree intervals drawn from the stack.

Distances drawn from the stack location were 0.4, 0.5, 0.55, 0.6, 0.65, 0.7, 0.8, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, and 1.7 kilometers. Corresponding elevations depicting the intersection of the 36 lines at 10 degree intervals with the concentric circles representing the above distances are attached.

The elevation of the stack base is at 244' MSL. The stack location was pin-pointed by using an aerial photograph to interpret the stack location on the topographic map.

Elevations below the stack's base elevation were plotted at the 244' MSL elevation. Thus, all 244' elevations are at stack ground elevation or below.

### MAP SCALE*

| Series | Scale | One Inch Represents |
|---|---|---|
| Draft of 7.5-minute | 1:24,000 | 0.61 km |
| Enlarged Scale | | 0.305 km |

* Map was enlarged to twice this scale.

525

DISTANCES FROM STACK

10° INTERVAL LINES

| km | 0.4 | 0,8 | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 244 | 250 | 244 | 244 | 244 | 244 | 244 | 244 | 250 | 2 |
| 2 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 255 | 255 | 2 |
| 3 | 244 | 244 | 244 | 244 | 255 | 260 | 250 | 250 | 244 | 4 |
| 4 | 244 | 244 | 244 | 244 | 265 | 250 | 255 | 244 | 244 | |
| 5 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 6 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 7 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 8 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 250 | 1 |
| 9 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 10 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 11 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 12 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 13 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 14 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 15 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 16 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 17 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 18 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 19 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | 244 | |
| 20 | 244 | 250 | 250 | 244 | 244 | 244 | 250 | 244 | 244 | 3 |
| 21 | 244 | 250 | 250 | 244 | 244 | 244 | 250 | 270 | 255 | 5 |
| 22 | 244 | 270 | 255 | 255 | 260 | 265 | 260 | 244 | 244 | 6 |
| 23 | 244 | 265 | 244 | 244 | 244 | 250 | 244 | 260 | 244 | 3 |
| 24 | 244 | 255 | 255 | 244 | 244 | 244 | 244 | 244 | 244 | 2 |
| 25 | 244 | 244 | 255 | 250 | 244 | 244 | 244 | 244 | 244 | 2 |
| 26 | 244 | 244 | 250 | 244 | 244 | 244 | 244 | 250 | 260 | 3 |
| 27 | 244 | 244 | 270 | 255 | 244 | 244 | 244 | 244 | 244 | 2 |
| 28 | 244 | 265 | 270 | 255 | 244 | 244 | 250 | 260 | 265 | 6 |
| 29 | 244 | 244 | 270 | 265 | 250 | 244 | 250 | 260 | 260 | 6 |
| 30 | 244 | 244 | 270 | 265 | 260 | 265 | 270 | 270 | 270 | 7 |
| 31 | 244 | 244 | 285 | 290 | 280 | 280 | 290 | 290 | 270 | 7 |
| 32 | 244 | 244 | 270 | 275 | 290 | 285 | 270 | 275 | 270 | 7 |
| 33 | 244 | 244 | 270 | 265 | 260 | 270 | 265 | 250 | 260 | 7 |
| 34 | 244 | 260 | 255 | 244 | 244 | 244 | 250 | 260 | 275 | 5 |
| 35 | 244 | 260 | 244 | 244 | 260 | 265 | 265 | 260 | 250 | 5 |
| 36 | 244 | 270 | 244 | 244 | 244 | 244 | 244 | 255 | 244 | 5 |
| | 0 | 10 | 14 | 9 | 9 | 9 | 13 | 14 | 13 | Elevations Higher Than Stack Elevation At Ground Level |

DISTANCES FROM STACK

10$^{0}$ INTERVAL LINES

| km | .5 | .55 | .6 | .65 | .7 |
|---|---|---|---|---|---|
| 1 | 244 | 244 | 244 | 250 | 250 |
| 2 | 244 | 244 | 244 | 244 | 244 |
| 3 | 244 | 244 | 244 | 244 | 244 |
| 4 | 244 | 244 | 244 | 244 | 244 |
| 5 | 244 | 244 | 244 | 244 | 244 |
| 6 | 244 | 244 | 244 | 244 | 244 |
| 7 | 244 | 244 | 244 | 244 | 244 |
| 8 | 244 | 244 | 244 | 244 | 244 |
| 9 | 244 | 244 | 244 | 244 | 244 |
| 10 | 244 | 244 | 244 | 244 | 244 |
| 11 | 244 | 244 | 244 | 244 | 244 |
| 12 | 244 | 244 | 244 | 244 | 244 |
| 13 | 244 | 244 | 244 | 244 | 244 |
| 14 | 244 | 244 | 244 | 244 | 244 |
| 15 | 244 | 244 | 244 | 244 | 244 |
| 16 | 244 | 244 | 244 | 244 | 244 |
| 17 | 244 | 244 | 244 | 244 | 244 |
| 18 | 244 | 244 | 244 | 244 | 244 |
| 19 | 244 | 244 | 244 | 244 | 244 |
| 20 | 244 | 244 | 244 | 244 | 244 |
| 21 | 244 | 244 | 250 | 255 | 260 |
| 22 | 244 | 250 | 260 | 265 | 270 |
| 23 | 250 | 250 | 244 | 250 | 260 |
| 24 | 244 | 244 | 244 | 244 | 250 |
| 25 | 244 | 244 | 244 | 244 | 244 |
| 26 | 244 | 244 | 244 | 244 | 244 |
| 27 | 244 | 244 | 244 | 244 | 244 |
| 28 | 244 | 244 | 250 | 250 | 250 |
| 29 | 244 | 244 | 250 | 250 | 250 |
| 30 | 244 | 244 | 250 | 250 | 244 |
| 31 | 244 | 244 | 244 | 244 | 244 |
| 32 | 244 | 244 | 244 | 244 | 244 |
| 33 | 244 | 244 | 244 | 244 | 244 |
| 34 | 244 | 250 | 250 | 250 | 244 |
| 35 | 255 | 265 | 270 | 270 | 270 |
| 36 | 250 | 260 | 265 | 265 | 265 |

# Division 8

# Considerations of Risks and Benefits/Alternatives Concerning PCB Incineration in Region 6

NOTE: Final analytical data (Appendix E) contains some small differences from the data used in this analysis. The effect is to reduce the anticipated risks in most cases, but in no instance is the change substantial.

# I. Risk Elements

## A. Introduction

Central to the operation of TSCA is the concept of unreasonable risk to human health or the environment. Figure I illustrates the process by which this determination is made. First, the inherent toxicity hazards posed by a chemical or process are identified. This information is generated by laboratory experiments, field studies, epidemiological investigations, etc.

Second, data are gathered on the exposures which are likely to result. This includes information on the populations which might be exposed and the frequency, duration, and the intensity with which such exposures are likely to occur. These data are observed by direct monitoring and/or mathematical modeling of the local situation.

Third, the risk is determined as a result of a consideration of toxicity and exposure. If either factor is zero, the risk is zero. In the case of cancer toxicity, the Agency has adopted a method of analysis which permits a quantitative estimate of the associated risk. In the case of other toxicities, the Agency presents a qualitative risk assessment.

Fourth, the benefits associated with the use of a chemical are usually considered. In this instance, however, Congress has mandated that any benefits of PCBs are outweighed by the risk they present and that the PCBs will be removed and go through some sort of a disposal process. The benefits referred to here are the benefits (or reduction of risks and/or costs) to be gained from the incineration of PCBs, compared to alternative modes of handling the materials, including storage. Such an analysis should include such factors as economics and timeliness.

Finally, the judgment of unreasonable risk is made by weighing the risk and the benefits involved. Since a)only some elements of the risk analysis are quantitative in nature and b) the benefits are sometimes measured in non-commensurable terms (e.g., dollar costs for disposal vs. predicted number of lives saved), a quantitative statement of unreasonable risk using the same units of measurement is impossible. From an examination of the risk/benefit analysis, however, the decision-maker can render a judgment concerning the "unreasonableness" of any risk.

## A. Toxicity Hazard

### 1. Structure-Activity Relationships between TCDD and TCDF

Since the late 1960s scientific and public interest has grown as information has become available about the extreme toxicity of 2,3,7,8 tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) (McConnell, 1978; Lucier, 1973).

This concern has resulted from such events as:

a. the suspension of the use of Agent Orange herbicide (contaiminated with 2,3,7,8-TCDD) in Viet Nam;

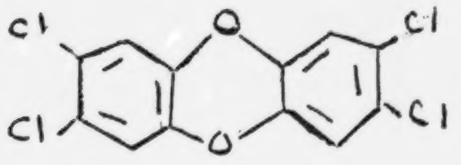
b. the cancellation of the use of 2,4,5-T (contaminated with 2,3,7,8-TCDD) in Sweden;

c. industrial accidents of the type that occurred in Seveso, Italy in 1976 which resulted in human expsoure to 2,3,7,8-TCDD;

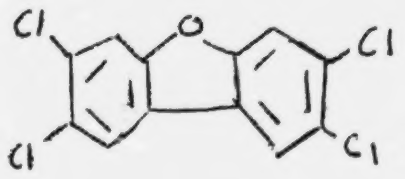
d. the suspension of certain uses of 2,4,5-T (contaminated with 2,3,7,8-TCDD) in the U.S.

While considerable attention has been directed at the toxicity of 2,3,7,8- and other isomeric forms of TCDDs, only a limited amount of information has been gathered on the analogous TCDF compounds; e.g., 2,3,7,8-TCDF.

Structure



2,3,7,8-TCDD



2,3,7,8-TCDF

The data which have been generated on the furan derivative, however, suggest comparable and parallel toxicities between related isomeric forms of TCDF and TCDD. This similarity in toxic properties should be expected in light of the similarity in chemical structures involved. In fact, the work of Poland puts forth a model of toxicity of certain halogenated ring systems which links potency to geometric dimensions of the molecule and position of halogen substitution on the rings (Poland, 1973;1976;1979). This model predicts that the toxic behavior of 2,3,7,8-TCDD and 2,3,7,8-TCDF will be closely related.

Moore cites the simliarity in the types of toxic effects produced by 2,3,7,8-TCDD and 2,3,7,8-TCDF (Moore, et al, 1979). At the same time, however, there is a quantitative difference in their acute toxicities with the furan derivative being less potent than the comparable dioxin. (See Table 2-1) The table also illustrates the marked, similar, species variation associated with the toxicity of these compounds.

Likewise, animal species are also less sensitive to the chronic effects of 2,3,7,8-TCDF than they are to those of 2,3,7,8-TCDD. For example, the disease pattern produced by the two substance is the same in mice, but the dose of the TCDF required to produce certain organ weight effects is approximately 30 times greater for the furan than for the dioxin. In addition, the ability of TCDF to induce hepatic aryl hydrocarbon hydroxylase (AHH), a biochemical response which has been associated with the mechanism of toxicity (Poland, 1979), is about 100-fold lower than that of TCDD (6) (Bradlaw, et al, 1979).

The cause for this reduced susceptibility to TCDF compared to TCDD is being investigated. Recent speculation suggests that the variance is related to differences in metabolism, with the TCDF being enzymatically attacked and cleared from the body more rapidly than TCDD.

As noted above, the quantity of data which has been generated on the furans is less than that on the dioxins. This is particularly true in the case of cancer. While the evidence cited here might suggest that TCDF would be a weaker carcinogen than TCDD, the upper limit of risk (ULOR) assessment developed in this paper will utilize TCDD data as a surrogate for missing TCDF information. The Agency believes that this is a conservative assumption (possibility erring on the side of public safety), given the extreme toxicity of 2,3,7,8-TCDD and the reduced potency of 2,3,7,8-TCDF in the effects which have been studied to date. The toxicity of both classes of substances will be reviewed below.

## 2. Relative Toxicity of Isomers

Most of the toxicity hazard information available on TCDDs is centered on the 2,3,7,8-isomer. The data that do exist on the relative toxicities of the other isomeric forms (Reggiani, 1980) suggest that the 2,3,7,8-isomer is the most toxic and that the major toxic manifestations appear when at least three of the positions--

2,3,7,and 8--are substituted with chlorine (Poland, 1979). Consequently, in order to more accurately assess the toxicity associated with TCDD (or TCDF), it is desirable to ascertain the distribution of isomeric forms in the sample.

In recent years synthetic and analytical chemists have succeeded in synthesizing and characterizing all 22 of the possible TCDD isomers (Nestrick, 1979;1980). The use of these isomers as standards has made possible the analysis of environmental samples for the specific amounts of 2,3,7,8-TCDD and other isomers present.

Unfortunately, the same situation does not extend to the TCDFs. In this case there are a total of 35 isomers possible. EPA analysts have fewer than 5 of these standards. Fortunately, one of the isomers in hand is the 2,3,7,8-TCDF isomer, which is thought, by analogy to the TCDD isomers, to be the most toxic. The availability of this standard allows the analyst to determine if a particular peak in his chromatogram is possibly the 2,3,7,8-TCDF isomer. Such a peak, however, could result from a subset of the TCDF isomers which have chromatographic properties identical to the 2,3,7,8-isomer. The number and identity of isomers in this subset cannot be determined unless all 35 standards are available. In this paper the Agency will make the conservative assumption that all TCDFs eluting from the chromatograph with the 2,3,7,8-TCDF isomer are exclusively the 2,3,7,8-isomer.

## 3. Toxicity Hazard

As noted in Table 2-1, the acute LD50s of the TCDD and TCDF are similar, with the furan being somewhat less potent that the dioxin. In each case the syndrome associated with death is a generalized wasting away. Attempts to identify the precise biochemical mechanism(s) involved have been unsuccessful (Neal, 1979). As noted earlier, there is considerable variation in the responses of different animal species to similar doses. Other toxic effects of TCDD and TCDF observed in non-humans are found in Table 2-2.

Dermal adminstration of these materials at doses as low as 10-20 ug can result in a persistent acne-like condition, called chloracne, in both rabbits and humans, which, while not life threatening, can be disfiguring. Chloracne in humans has been considered to be unequivocal evidence of exposure to certain halogenated hydrocarbons, including TCDD and TCDF.

The involution observed in the thymus of animals strongly suggests that the TCDD may have an effect on the organism's ability to defend itself through an immunological response. There is clear evidence of damage to the liver, reminiscent of the action of other chlorinated hydrocarbons.

The reproductive effects produced in rats (reduced numbers and weights of offspring) are of particular concern in light of the low doses at which effects are observed (0.001 ug/kg-day). In fact, the Agency has taken the position that no "no observed effect level" (NOEL) has been demonstrated for reproductive effects.

Mutagenicity studies have resulted in a range of responses in the hands of different investigators. A carefully controlled study from the National Institutes of Environmental Health Sciences (NIEHS) is about to be released.

Recent studies by the National Cancer Institute have demonstrated the carcinogenic activity of TCDD in both rats and mice at low doses (0.001 ug/kg-day) (National Cancer Institute, 1980). Similar data obtained by researchers at Dow Chemical Co. (Kociba, 1978) have formed the basis of the risk assessment developed by the Agency's Carcinogen Assessment Group(CAG). The Dow data have been used in a multi-stage linear extrapolation model which relates any exposure level with a predicted excess risk of cancer (Carcinogen Assessment Group, 1980a).

Table 2-3 is a summary of the toxic effects which have been attributed to TCDD-related exposures in humans.

The Agency's position on the toxicity of 2,3,7,8-TCDD is more fully developed in the position document on 2,4,5-T (EPA, 1978) and in the 2,4,5-T cancellation hearings now in progress.

## II. Exposure Assessment

This ULOR/benefit assessment addresses two particular sites in Region 6. While the toxic emissions of interest are the same in both cases, the elements of exposure differ. This section discusses the unique features of the two locations, the populations at risk, and the emissions.

### A. Populations at Risk

#### 1. Rollins at Deer Park, Texas

##### a. Surroundings

The Rollins Environmental Services facility is located on the south side of the Houston Ship Channel, about 4,000 feet to the southwest of the shoreline. It is in the middle of one of the most densely industrialized areas in the nation. From the Ship Channel's Turning Basin at the edge of downtown Houston, to the Bayport Bridge, the ship channel is lined on both sides with industrial complexes. Because of the complete lack of zoning regulations in the area, these industrial districts are closely flanked by residential neighborhoods and small incorporated townships. Within the area of concern for emissions from Rollins there are two townships: Deer Park and Deepwater. These are located to the south and southwest of the Rollins plant site, with the most populous portions of both towns lying within three miles of the site.

The ecological character of the region is that of a coastal short-grass prairie. There are no known characteristics of the flora or fauna which would make them especially susceptible to or immune from contamination by dioxins or furans.

The land use figures shown in Table 3-1 are based on a water quality planning survey which did not include any of the nearby townships. The estimates of the total area, including the towns, are given in parentheses.

### b. Distribution of Population

The Agency estimates that up to 25,000 people could experience exposure to some level of emissions from the incinerator. Within a radius of one mile the only exposed population is a group of employees of the nearby industries. These would be subject to an eight-hour exposure. Within a two-mile radius is the most densely populated center of Deer Park. A three mile radius takes in about 1/3 of the most densely populated section of the town of Deepwater.

## 2. ENSCO at El Dorado, Arkansas

### a. Surroundings

El Dorado, Arkansas is known as the capital of the petroleum and chemical industry in the State. This is a relative term, since the bulk of Arkansas is strictly rural in nature. Table 3-2 shows that 90% of the area around El Dorado is forest.

The area presents a topography of gently rolling hills rising to an elevation of about 260 feet above sea level, with the intervening valleys at about 180 to 200 feet elevation. The ENSCO facility itself is located to the east of El Dorado in a small industrial park. There are several small communities, including churches and other public facilties, adjacent to the plant boundaries.

The surrounding forest is a mixture of deciduous and coniferous trees with typical upland animal species. There is a small area (3% of the total) of wetlands to the south. While the effects of chlorinated dibenzodioxins and furans on such environmental systems have not been studies in detail, the persistence and potential for bioaccumulation of these materials have been documented.

### b. Distribution of Population

The population of El Dorado is about 25,000. Another 24,000 people live within the maximum limits to which the air dispersion modeling of ENSCO's emissions will be applied.

- El Dorado has the fourth highest per capita income in Arkansas, with most of this coming from manufacturing, wholesale and retail sales, and services.

## B. Exposure

### 1. Intensity

#### a. Sampling

In the fall of 1980 EPA personnel at Headquarters and in Region 6 devised a stack sampling scheme to assess the presence, if any, and extent of emissions of tetrachlordibenzo-p-dioxins (TCDDs) and tetrachlorodibenzofurans(TCDFs) from the Rollins and ENSCO incinerators. The report prepared by the contractor for the project contains the details of this activity (TRW, 1980b).

At each site a series of three test burns was conducted.

Test 1--Regular toxic wastes with which PCBs would be burned.

Test 2--Regular toxic wastes burned along with PCBs.

Test 3--PCBs burned with special supplementary fuel.
The intent of the study was to identify and quantify any contribution of PCBs to TCDD and/or TCDF production.

After the sampling, the probe was washed off and the resulting liquid analyzed. The impinger catch consisted of two phases: an organic phase and an aqueous phase, each of which was analyzed. The resins were extracted with hot organic solvent to give an extract which was also analyzed.

### b. Analysis

All of the samples were sent to the Wright State University laboratory of Dr. Thomas Tiernan in Dayton, Ohio, for analysis by high resolution gas chromatography, coupled to a high resolution mass spectrometer (HR GC/MS). The samples were first analyzed for total TCDD and then specifically for 2,3,7,8-TCDD. Next, the samples were analyzed for total TCDF on a low resolution mass spectrometer. Finally, quantitation was made of 2,3,7,8-TCDF.

Table 3-3 summarizes the findings from each test at each site. Table 3-4 converts these data into the implied mass emission rates (Region 6, 1980a).

### c. Modeling

Humans, of course, are not exposed to incineration products as they make their way up the stack. Human exposure occurs when the stack emissions are dispersed through their encounter with the air and make their way down to the levels which constitute the breathing zones of people.

Since it is this breathing zone that is of primary importance in assessing risk to human health, it would seem that sampling the ambient environment would provide a more direct measure than would stack sampling. As a practial matter, however, even the parts per trillion (ppt) level of sensitivity achieved by HR GC/MS is not sufficient to detect TCDD and TCDF at the levels of concentration anticipated to be present in the breathing zone, without sampling massive volumes of air, a procedure which itself is open to question for these chemicals. (Lewis, 1980).

Consequently, computer modeling has been used to predict the dispersion of the components found in the stack sampling, with the assumption that the nature and relative composition of the components remain unchanged.

Region 6 has conducted the computer modeling for each of the two sites (Region 6, 198 0b). Table 3-5 summarizes these results by citing the predicted maximum annual average concentrations of TCDD and TCDF a) anywhere within the area and b) in the residential communities within the area. (In the case of ENSCO these points coincide.) Note that these maximum concentrations exit for only a small portion of the area surrounding the stack. For example, only people living directly downwind of the prevailing winds will experience this maximum concentration. In addition, people living closer to the stack or farther from it will be subjected to lower concentrations than those living at a distance where the plume first comes to ground.

This paper makes the assumption that all people (upwind, downwind, near the stack, far from the stack, etc.) are subjected to the same maximum average concentration. While this assumption is obviously extreme, it does contribute to making this an upper limit of risk estimation.

## 2. Frequency and Duration

It is unclear at this point just how frequently PCBs will be burned at Rollins and/or ENSCO. As related in Section V below (Benefits/Alternatives), however, there is only a finite amount of PCBs a)currently awaiting dispoal or b)scheduled for disposal during the next twenty years when the electrical equipment in which they are contained are removed from service. It has been estimated (Gunter, 1981) that if Rollins devoted itself for 20 hours/day to burning liquid PCBs, the entire inventory of the nation's supply of these materials would be removed in 35 years. Since the feed rate at ENSCO is less, the time to incinerate the nation's inventory would be longer by a factor of 10. Although such a senario is highly unlikely, this paper will make the worst case assumption that the exposed population will be exposed for their full lifetimes. Such an assumption again errs on the side of public safety.

# IV. Risk Assessment

## A. Assumptions

As the risk assessment is developed, it is important to keep in mind some of the underlying, as well as explicit, assumptions which are being made. These are summarized in Table 4-1.

## B. Qualitative risk assessment

Table 4-2 summarizes

a. the toxic effects observed in animals treated with 2,3,7,8-TCDD

b. the lowest dose tested at which an effect is observed

c. the dose expected to be received by a 60 kg female breathing the predicted maximum average annual concentration of TCDD and TCDF emitted by the ENSCO facility.

d. the same value at Rollins

e. the ratio of the animal dose to the ENSCO dose

f. the ratio of the animal dose to the Rollins dose

These data suggest that a large margin of safety exists between the animal doses and the maximum conceivable doses resulting from PCB incineration at ENSCO and Rollins.

## C. Quantitative Risk Assessment for Cancer

Recently the Agency's Carcinogen Assessment Group (CAG) has prepared a quantitative risk assessment for 2,3,7,8 TCDD for use in the on-going 2,4,5-T cancellation hearing. In addition, CAG has used some of the same data to prepare a 2,3,7,8-TCDD unit risk assessment for EPA's Office of Air Quality Planning and Standards (OAQPS). This latter document estimates that the risk factor associated with breathing air containing $1x10^{-9}$ g (1 nanogram) of 2,3,7,8-TCDD per cubic meter (1 $ng/m^3$) is .091. This means that if 1000 people breathe air containing this concentration of TCDD through a 70-year lifetime, 91 cases of cancer are predicted to occur in excess of what otherwise would have occured.

Applying this unit risk factor to the predicted concentrations at ENSCO and Rollins, Table 4-3 displays the resulting predicted cancer risks associated with the maximum annual concentration of TCDD and TCDF during the incineration of PCBs (Test 2). At ENSCO this risk is between .4 in a million (4 in 10,000,000 chances) and .1 in a million (1 in 10,000,000). At Rollins the risk of an additional cancer is between 18 in a million (180 in 10,000,000) and .1 in a million (1 in 10,000,000), depending on whether one is concerned with the maximum risk in the entire area or just within the residential communities.

These are the risks which would arise at the point of maximum concentration. People living in other locations would be subjected to lesser risks

Assuming the worst case, Table 4-4 shows the risks for the populations involved.

## V. Benefits/Alternatives

As noted above, by legislating the disposal of PCBs from the environment, Congress effectively decided that there were no benefits associated with these materials that would justify the risks they posed. Consequently, the only point at issue here is whether the risks associated with incineration are justified in terms of alternative forms of disposal. The alternatives to be considered are:

a. landfilling
b. storage
c. chemical destruction

As background it is important to keep in mind that the nation has an inventory of 750,000,000 lbs of PCBs, virtually all of which is in "totally enclosed" forms (capcitors and transformers) which will come out of service over the next 20 years. There are 582,000,000 pounds of PCBs which will require special disposal. 168,000,000 pounds are in capacitors of types that will not require special disposal. 300 of the 582 million pounds of pure PCBs are in transformers and comprise about 25% of the total weight of the liquid material from such transformers requiring incineration. The remaining 282 million pounds of PCBs are in capacitors subject to incineration requirements and constitute approximately 20% of the weight of the solid material comprising those capacitors.

A. Landfilling

In the PCB regulations the Agency views landfilling as a less than desirable ultimate answer to PCB disposal. Given the pressure to provide some disposal means until incineration facilties could be approved, however, the Agency established a limited, tightly restricted landfill option for capacitors (not transformer liquids) which will expire in March, 1981. The risks and cost limitations involved with this option include the following:

a. Risks: There is an unknown, but finite, possibility of movement of PCBs from the landfill site with a resulting human exposure through groundwater contamination and accumulation in the food chain. This risk, which is not easily quantified, is reduced by trying to insure near-zero exposure through the use of appropriate technologies. Through landfilling the risk is reduced and retained, rather than removed and eliminated.

b. Expense: The estimated costs are $1/gal plus $3/loaded mile for transportation (Gunter, 1981).

c. Limited capacity: At the moment only 8 landfills in the country are approved for disposal for PCB capacitors.

B. Storage

The strategy here is the same as that for landfilling: reduce the risk by reducing the exposure. A similar list of risks, costs, and limitations exist for this option.

a. Risks: The storage of PCBs as outlined in the rule is intended to be preliminary to disposal; not a substitute for disposal. With approximately 2 million gallons of PCB liquids presently in storage, and more PCBs being removed from service everyday, the potential for a spill during handling or transport associated with storage continues to increase.

In the absence of some permanent disposal method, persons storing PCBs could limit this expense in two ways: 1)illegal disposal or 2)legal action against EPA for having issued an unworkable regulation and asking a court to weaken the existing disposal regulation to allow such alternatives as the landfilling of liquids with high PCB concentrations.

b. Expense: The estimated costs are $17,000/utility for 6 months of storage for transformers and $34,000/utility for 6 months of storage for capacitors (Gunter, 1981).

c. Limited capcaity: All current capacity has been utilized. New storage facilities are having to be built.

C. Chemical destruction methods

At least two chemical destruction methods have recently been developed which hold considerable promise. Advantages assocated with one or both of these systems include:

1. Reduction of risk by removal of hazard. By transforming the toxic PCBs into innocuous materials, the risk is absolutely and permanently eliminated.

2. Promise of portability: Portable rigs can be constructed to go to the PCBs, rather than visa versa. This removes the risk associated with the transport of PCBs.

These advantages are accompanied by certain limitations.

1. Current technology is designed to only handle dilute (less than 500 ppm) solutions of PCBs The problem of concentrated PCB systems would remain.

2. The methods cannot handle the "solid problem"; i.e., destruction of the PCBs in capacitors.

3. Limited accessibility: No group has come forward to develop the Goodyear process. Sunohio is developing mobile units which will service PCBs in transformers, but they will be limited in their ability to visit all sites.

4. Capacity: The Sunohio unit can handle 1000 gal/day.

Therefore, while chemical destruction methods can be anticipated to destroy a certain fraction and type of PCBs in the coming years, the technology does not have the capability nor the capacity to deal, by itself, with the problem currently confronting the country.

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Table 1-1 (from Roggiani, 1980)

$LD_{50}$ (mg/kg bodyweight) of various PCBs (Arclors)

| Species (route) | 1221 | 1232 | 1242 | 1248 | 1254 | 1260 | 1262 |
|---|---|---|---|---|---|---|---|
| Mouse (oral) | | | | | 2'000 | | |
| Rat (oral) | 4'000 | 4'500 | 8'700 | 11'000 | | 10'000 | 11'300 |
| Adult rat (oral) | | | | | 4'000-10'000 | 4'000-10'000 | |
| Weaning rat (oral) | | | | | 1'300 | 1'300 | |
| Adult rat (i.v.) | | | | | 350 | | |
| 30 day old rat (oral) | | | | | 1'300-1'400 | | |
| 120 day old rat (oral) | | | | | 2'000-2'500 | | |
| Rabbit (skin) 501 solution MLD | 2'000-3'200 | 1'300-2'000 | 800-1'300 | 800-1'300 | | 1'300-2'000 | 1'300-3'200 |

Table 1-2. Summary of Chronic Effects of PCBs
(Adapted from National Research Council Report on PCBs)

| | |
|---|---|
| Health Concerns | |
| Oncogenicity | High chlorinated compounds produced tumors in rats and mice, relationship with PCB not always clear |
| Mutagenicity | Ames test - 1221, 4 chlorobiphenyl significantly mutagenic |
| | Dominant lethal mutations - negative results |
| | Chromosomal abnormalities - negative results |
| Teratogenicity | Effects seen in avian species, 50-200 ug/g |
| Other Effects in Mammals | Mouse - some liver change with exposure to high chlorine containing products, 300-500 ug/g |
| | Rat - some liver changes, minimal reproductive effects, 100-500 ug/g |
| | Monkey - Yusho symptoms, altered reproduction cycles, hyperplastic gastritis and ulceration, 2.5-5 ug/g |
| | Chicken - some morphologic deformity, reproduction decline, subcutaneous edema, 20-50 ug/g |
| | Dogs - reduced growth, some liver changes, 100 ug |
| | Mink - dose response relationship in growth and reproduction, 10 ug/g at levels of 2-5 ug/l |
| Environmental Concerns | |
| Ecotoxicity | Threshold effects in egg hatchibility of aquatic vertebrates and invertebrates at levels of 2-5 ug/l |

| | |
|---|---|
| Ecotoxicity ( cont'd.) | Aquatic embryo toxicity evident at 50 ug/l<br>Pelican - some hepatocellular changes, 100 ug<br>Wildfowl - some reproduction changes, varies with species, 50-200 ug/g |
| Additional Troublesome properties | Persistent<br>Bioaccumulates |

TABLE 2-1 Comparative Acute Oral Toxicity of 2,3,7,8-TCDD
and 2,3,7,8-TCDF
(Moore, 1979 as quoted in Reggiani, 1980)

| Species | LD50 TCDD (ug/kg) | LD50 TCDF (ug/kg) | Approx. $\frac{\text{LD50 TCDF}}{\text{LD50 TCDD}}$ |
|---|---|---|---|
| Guinea pig | 0.5-1.5 | 5 - 10 | 4 |
| Monkey | 30-70 | 1000 | 20 |
| Mouse | 150-300 | 6000 | 25 |

TABLE 2-2 Other Toxic Effects of 2,3,7,8-TCDD and 2,3,7,8-TCDF Observed in Non-Humans

| Effect | TCDD | TCDF |
|---|---|---|
| Chloracne | (Reggiani, 1980) | (Reggiani, 1980) |
| Thymus atrophy | (Gupta, 1973) | (Luster, 1979) |
| Liver effects | (Neal, 1979) | (Luster, 1979) |
| Reproductive effects | (Murray, 1978) | --------- |
| Weight loss | (Neal, 1979) | (Moore, 1979) |
| Mutagenicity | | --------- |
| Cancer | (Kociba, 1978) | --------- |
| Teratogenic effects | (Courtney, 1971) | --------- |

TABLE 2-3 Toxic Effects of 2,3,7,8-TCDD Reported in Humans (Reggiani, 1980)

Dermatological
- Chloracne
- Porphyria curanea tarda
- Hyperpigmentation and hirsutism

Internal
- Liver damage
- Raised serum hepatic enzyme levels
- Disorders of fat metabolism
- Disorders of carbohydrate metabolism
- Cardiovascular disorders
- Urinary tract disorders
- Respiratory tract disorders
- Pancreatic disorders

Neurological
- A. Peripheral
  - Polyneuropathies
  - Sensorial impairments
    - (Sight, hearing, smell, taste)
- B. Central
  - Lassitude, weakness, impotence
  - Loss of libido

TABLE 3-1 Land Use Patterns Near Deer Park, Texas[1]

| Land Use | Acres | % of Total |
|---|---|---|
| Total | 4491 (30,000) | |
| Residential and Built-Up | 0 (5,000) | 17 |
| Commercial and Service | 10 (500) | 2 |
| Industrial | 2658 (15,000) | 50 |
| Open (Parks, etc.) | 122 (300) | 1 |
| Agricultural | 0 | 9 |
| Vacant | 1402 (8,000) | 27 |
| Water | 299 (1,200) | 4 |

(1)from Houston-Galveston Area Council 208 planning documents

TABLE 3-2 Land Use Patterns for El Dorado, Arkansas[1]

| Land Use | Acres | % of Total |
|---|---|---|
| Total | 2,165,374 | |
| Urban and Built-Up | 89,963 | 2.1 |
| Residential | 14,896 | |
| Agricultural | 232,119 | 6.6 |
| Forests | 1,759,129 | 90 |
| Water Bodies | 13,096 | |
| Wetlands | 71,166 | |

(1) From 208 planning document

TABLE 3-3A Rollins Analytical Results in Nanograms
(detection limits in parentheses)

| Sample No. | Sample | Total TCDD | 2,3,7,8 TCDD | Percent Recovery | Total TCDF | 2,3,7,8 TCDF | Percent Recovery |
|---|---|---|---|---|---|---|---|
| | | | Test 1 | Train 1 | | | |
| 6-05-81 | Impinger | 1.79(.4) | | 100 | 3.5(.8) | .7 | 100+ |
| 6-05-82 | Probe wash | 3.84(.4) | | 100 | 5(.15) | .5 | 100 |
| 6-05-83[1] | XAD-2 | 1.31(.4) | | 100 | 5(.15) | .3 | 100 |
| 6-05-84[1] | Florisil | ND( ) | | 20 | | | |
| 6-05-85[1] | | | | | ND(.8) | ND | 100 |
| (1) Composited | | 6.94+ | | | 13.5+(.8) | 1.5+(.8) | |
| | | | Test 2 | Train 1 | | | |
| 6-06-05 | Impinger | ND(.27) | | 75 | 6.0(.1) | .8 | 72 |
| 6-06-06[1] | Probe wash | 1.42(.27) | | 129 | 14(1) | 1.4 | 122 |
| 6-06-07[1] | XAD-2A | ND(.38) | | 107 | 2(.07) | .25 | 100 |
| 6-06-08[1] | XAD-2B | | | | | | |
| 6-06-09 | Florisil | ND(.48) | | 79 | ND(.9) | ND(.9) | 85 |
| (1) Composited | | 1.42+(1.03) | | | 22+(.9) | 2.4+(.9) | |
| | | | Test 3 | Train 2 | | | |
| 6-06-43 | Impinger | ND(.9) | | 100 | ND(.2) | ND | 100+ |
| 6-06-44 | Probe wash | ND( ) | | | ND(.5) | ND | 60 |
| 6-06-45 | XAD-2 | ND(.3) | | 80 | 2(.1) | .2 | 72 |
| 6-06-46 | Florisil | ND(.3) | | 58 | ND(.4) | ND | 15 |
| | | ND+(1.55) | | | 2+(1.1) | .2+(1.1) | |

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## TABLE 3-3B ENSCO Analytical Results in Nanograms
(detection limits in parentheses)

| Sample No. | Sample | Total TCDD | 2,3,7,8 TCDD | Percent Recovery | Total TCDF | 2,3,7,8 TCDF | Percent Recovery |
|---|---|---|---|---|---|---|---|
| | | | Test 1 | Train 1 | | | |
| 6-05-27 | Impinger | (Sample expended in method development) | | | | | |
| 6-05-28 | Probe wash | .16(.06) | | 146 | ND(1) | ND | 50 |
| 6-05-29 | XAD-2A | .10(.06) | | 104 | ND(2) | ND | 15 |
| 6-05-30 | XAD-2B | ND(.07) | | 85 | ND(.1) | ND | 70 |
| 6-05-31 | Florisil | ND(.07) | | 128 | 2(.2) | .5 | 30 |
| | | .26+ (.14) | | | 2+ (3.1) | .5+ (3.1) | |
| | | | Test 2 | Train 1 | | | |
| 6-05-60 | Impinger | .48( ) | | 41 | 4(.5) | 1 | 100 |
| 6-05-61 | Probe wash | ND(.25) | | 97 | .5(.09) | .2 | 75 |
| 6-05-62 | XAD-2 | ND(.38) | | 134 | 1.5(.5) | .3 | 100+ |
| 6-05-63 | Florisil | ND(.66) | | 51 | ND(.8) | ND | 100 |
| | | .48+ (1.29) | | | 6+ (.8) | 1.5+ (.8) | |
| | | | Test 3 | Train 1 | | | |
| 6-05-74A | Impinger | ND(.35) | | 71 | ND(.5) | ND | 100+ |
| 6-05-74B | Probe wash | ND(.21) | | 98 | ND(.5) | ND | 100+ |
| 6-05-74C | XAD-2 | ND(.2) | | 94 | ND(.8) | ND | 100 |
| 6-05-74D | Florisil-A | ND(.2) | | 122 | ND(.4) | ND | 15 |
| 6-05-74E | Florisil-B | ND(.45) | | 46 | ND(1.9) | ND | 88 |
| | | (1.41) | | | (2.8) | (2.8) | |

TABLE 3-3C Summary of Analytical Results at ENSCO and Rollins in Nanograms
(Totals including detection limit values for NDs in ())

| Site | Total TCDD | 2,3,7,8 TCDD | Total TCDF | 2,3,7,8 TCDF | Total TCDD + TCDF | Total TCDD + 2,3,7,8-TCDF |
|---|---|---|---|---|---|---|
| ENSCO | | | | | | |
| Test 1 | .26+ (.40+) | | 2(5.1) | .5(3.6) | 2.39(5.5) | .76+ |
| Test 2 | .48(1.77) | | 6(6.8) | 1.5(2.3) | 6.48(8.6) | 2.0 |
| Test 3 | ND(1.41) | | ND(2.8) | ND(2.8) | ND(4.2) | ND |
| Rollins | | | | | | |
| Test 1 | 6.94(6.94+) | | 13.5(14.3) | 1.5(2.3) | 20.4(21.2+) | 8.4 |
| Test 2 | 1.42(2.45) | | 22(22.9) | 2.45(3.4) | 23.4(25.3) | 3.87 |
| Test 3 | ND(1.55) | | 2(3.1) | .2(1.3) | 2(4.7) | .2 |

TABLE 3-4 Mass Emission Rates (in ng/sec) of TCDD and TCDF
Found at Rollins and ENSCO
(Results including detection limit values for NDs in ())

| Site | Total TCDD | Total TCDF | Possible 2378 TCDF | Total TCDD Plus TCDF | Total possible TCDD plus 2378 TCDF[1] |
|---|---|---|---|---|---|
| ENSCO | | | | | |
| Test 1 | .95+ (1.46+ ) | 7.32+ (18.7+ ) | 1.83+ (6.6+ ) | 8.27+ (28.16+ ) | 2.78+ |
| Test 2 | 1.69(6.26) | 21.24(24.1) | 5.3(8.1) | 22.93 (30.4) | 6.99 |
| Test 3 | 0(5.26) | 0(10.44) | 0(10.44) | 0(15.70) | 0 |
| Rollins | | | | | |
| Test 1 | 43.74(43.74+ ) | 85.05(90.3) | 9.45(14.5) | 128.79(134) | 53.19 |
| Test 2 | 10.34(17.8) | 160.13(166.7) | 17.8(24.8) | 170.47(184) | 28.14 |
| Test 3 | 0(9.6) | 12.44(19.3) | 1.2(8.1) | 12.44(29.2) | 1.2 |

(1) Sum of columns 2 and 3

TABLE 3-5A Predicted Annual Average Concentration in ($10^{-6}ng/m^3$) of TCDD and TCDF in the Breathing Zone at Point of Highest Exposure in the Dispersion Area (Results including detection limit values for NDs in ())

| Site | Total TCDD | Total TCDF | Possible Possible 2378 TCDF | Total TCDD plus TCDF | Total Possible TCDD plus 2378 TCDF[1] |
|---|---|---|---|---|---|
| ENSCO | | | | | |
| Test 1 | (.209) | (2.67) | | (2.87) | 2.9 |
| Test 2 | .242(.895) | 3.04(3.44) | .758(1.16) | 3.28(4.35) | 1.4 |
| Test 3 | 0(.752) | 0(1.49) | | (2.24) | 0 |
| Rollins | | | | | |
| Test 1 | 46.8(46.8) | 91(96.4) | 10(15) | 138(143) | 61.8 |
| Test 2 | 11.1(19.1) | 172(178) | 19(27) | 183(197) | 30 |
| Test 3 | 0(10) | 13(21) | 1(9) | 12(31) | 1 |

B. Predicted Annual Average Concentration (in $10^{-6}$ $ng/m^3$) in the breathing zone in residential area

ENSCO -- Same as above

| | | | | | |
|---|---|---|---|---|---|
| Rollins | | | | | |
| Test 1 | 2.18(2.18+) | 4.24(4.50) | .47(.72) | 6.42(6.68) | 2.65 |
| Test 2 | .52(.89) | 7.98(8.31) | .89(1.24) | 8.50(9.17) | 1.41 |
| Test 3 | 0(.48) | .62(.96) | .06((.40) | .62(1.45) | .06 |

### Table 4-1 Assmuptions

1. Identity in the carcinogenicity of 2,3,7,8-TCDD and 2,3,7,8-TCDF
2. All TCDDs and TCDFs have the same carcinogenicity potential as 2,3,7,8-TCDF
3. All emissions from the stack are respirable and are retained in the body
4. All the TCDD and TCDF that is respired is retained and is biologically available to the organism even though some significant fraction is tenaciously bound in or on the emission particles
5. The composition of the emission products found in the stack is identical to the composition (but not the concentration) found at the ground level
6. The combustion of the PCBs would continue for 24 hours a day for a 70 year lifetime
7. The air dispersion modeling is representative of what happens at the two sites
8. The entire population is subjected to the maximum average annual concentration found at the point of highest concentration.
9. The multi-stage, one-hit, linear extrapolation method of cancer risk assessment is valid.
10. Laboratory animals are faithful surrogates for humans
11. The other assumptions for cancer risk assessment as found in FR 44 131, July 6, 1979 are valid
12. The assumptions made by the Cancer Assessment Group in determinimg unit risk assessments for the Air Programs are valid (Cancer Assessment Group, 1980b).

Table 4-2 Qualitative Risk Estimate

| Effect | Lowest<br>Lowest 2378 TCDD Dose (ng/kg/day) | Maximum TCDD + TCDF ENSCO Dose[1] (ng/kg/day) | TCDD + TCDF Rollins Dose[2] (ng/kg/day) | Column 2 value / Column 3 value | Column 2 value / Column 3 value |
|---|---|---|---|---|---|
| Thymus atrophy | 6 [3] | $1.45 \times 10^{-6}$ | $66 \times 10^{-6}$ | 1,000,000 | 30,000 |
| Reproductive | 1 [4] | $1.45 \times 10^{-6}$ | $66 \times 10^{-6}$ | 200,000 | 5,000 |
| Teratogenicity | 1 [5] | $1.45 \times 10^{-6}$ | $66 \times 10^{-6}$ | 200,000 | 5,000 |

(1) (Table 3-5A value of $4.35 \times 10^{-6}$ ng/m$^3$) x (20 m$^3$/day) x (1/60 kg)
(2) (Table 3-5A value of $197 \times 10^{-6}$ ng/m$^3$) x (20 m$^3$/day) x (1/60 kg)
(3) Vos, 1973
(4) Murray, 1978
(5) Smith, 1976

## TABLE 4-3 Range of Risks
Expressed in chances out of a million

A. At point of maximum concentration in the dispersion model area

| Site | Maximum possible values of total TCDD and TCDF[1] | Analytical values of TCDD plus possible 2,3,7,8-TCDF[2] |
|---|---|---|
| ENSCO | | |
| Test 1 | .3 | .03 |
| Test 2 | .4 | .1 |
| Test 3 | .1 | 0 |
| Rollins | | |
| Test 1 | 13 | 6 |
| Test 2 | 18 | 3 |
| Test 3 | 3 | .1 |

B. At point of maximum conentration in residential area

ENSCO -- Same as above

| | | |
|---|---|---|
| Rollins | | |
| Test 1 | .6 | .2 |
| Test 2 | .8 | .1 |
| Test 3 | .1 | .005 |

(1) Based on values of column 5 in parentheses in Table 3-5
(2) Based on values of column 6 in Table 3-5

TABLE 5-1 Amount of Materials with PCBs >500 ppm
(Gunter, 1981)

| Type | Ready for Immediate disposal | Retiring within 20 years |
|---|---|---|
| Transformer liquids | 20,000,000 lbs | 280,000,000 lbs |
| Capacitors | 10,000,000 lbs | 440,000,000 lbs |

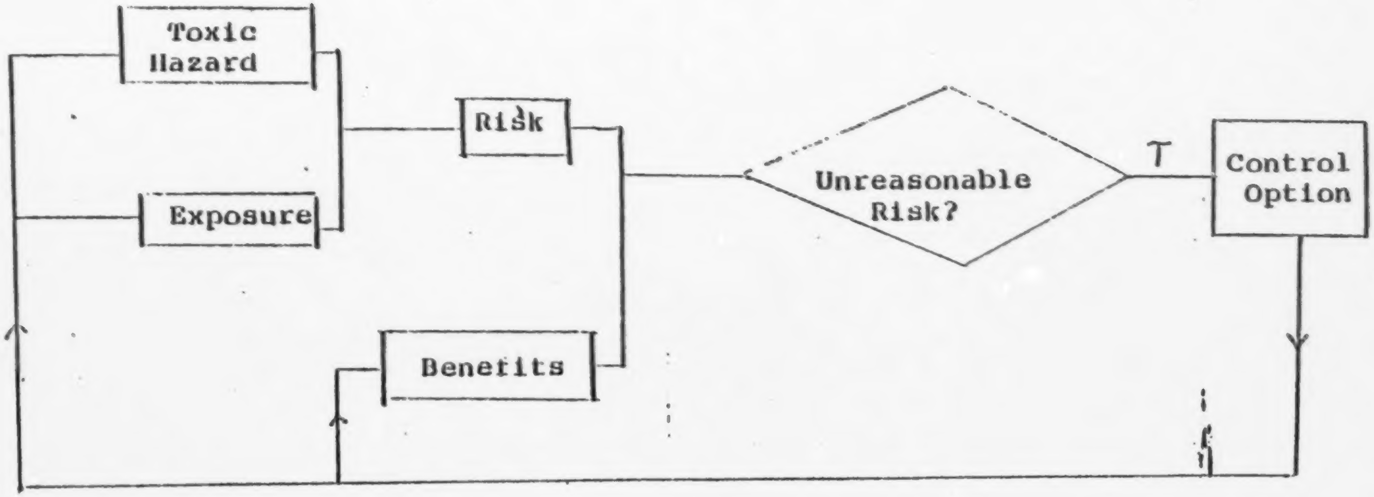

Fig I    Unreasonable risk determination

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United States
Environmental Protection
Agency

Office of Research and Development

PROBLEM ORIENTED REPORT

# METHOD FOR DETERMINING THE UNIT RISK ESTIMATE FOR AIR POLLUTANTS

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Prepared for:

Office of Air Quality Planning and Standards
Office of Air, Noise and Radiation
U. S. Environmental Protection Agency

Prepared by:

Carcinogen Assessment Group
Office of Health and Environmental Assessment
Office of Research and Development
U. S. Environmental Protection Agency

# THE CARCINOGEN ASSESSMENT GROUP'S
# METHOD FOR DETERMINING THE UNIT RISK ESTIMATE
# FOR AIR POLLUTANTS

Robert E. McGaugh
For Roy E. Albert, M.D.
Chairman
July 31, 1980

PARTICIPATING MEMBERS

Elizabeth L. Anderson, Ph.D.
Larry Anderson, Ph.D.
Dolph Arnicar, B.A.
Steven Bayard, Ph.D.
David L. Bayliss, M.S.
Chao W. Chen, Ph.D.
John R. Fowle III, Ph.D.
Bernard Haberman, D.V.M., M.S.
Charalingayya Hiremath, Ph.D.
Chang S. Lao, Ph.D.
Robert McGaughy, Ph.D.
Jeffrey Rosenblatt, B.S.
Dharm V. Singh, D.V.M., Ph.D.
Todd W. Thorslund, Sc.D.

# METHOD FOR DETERMINING THE UNIT RISK ESTIMATE FOR AIR POLLUTANTS

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## INTRODUCTION

The unit risk estimate for an air pollutant is defined as the lifetime cancer risk occurring in a hypothetical population in which all individuals are exposed continuously from birth throughout their lifetimes to a concentration of 1 ug/m$^3$ of the agent in the air which they breathe. This calculation is done to estimate in quantitative terms the effectiveness (potency) of the agent as a carcinogen. Unit risk estimates are used for two purposes: 1) to compare the carcinogenic potency of several agents with each other, and 2) to give a crude indication of the population risk which might be associated with air exposure to these agents, if the actual exposures are known. These two uses have different limitations.

In order to use these estimates intelligently, the nature of the source data used and the assumptions necessary to derive the estimates must be clearly understood. This appendix discusses the general approach and the assumptions common to most unit risk estimates. The credence one can ascribe to each risk estimate depends heavily on the quality of the studies on which the estimate is based and the relevance of these studies to the evaluation of air exposure in humans.

## PROCEDURES FOR DETERMINATION OF UNIT RISK

The data used for the quantitative estimate is one or both of two types: 1) lifetime animal studies, and 2) human studies where excess cancer risk has been associated with exposure to the agent. In animal studies it is assumed, unless evidence exists to the contrary, that if a carcinogenic response occurs at the dose levels used in the study, then responses will also occur at all lower doses with an incidence determined by the extrapolation model discussed below.

## A. Choice of Model

There is no really solid scientific basis for any mathematical extrapolation model which relates carcinogen exposure to cancer risks at the extremely low concentrations that must be dealt with in evaluating environmental hazards. For practical reasons such low levels of risk cannot be measured directly either by animal experiments or by epidemiologic studies. We must, therefore, depend on our current understanding of the mechanisms of carcinogens for guidance as to which risk model to use. At the present time the dominant view of the carcinogenic process involves the concept that most agents which cause cancer also cause irreversible damage to DNA. This position is reflected by the fact that a very large proportion of agents which cause cancer are also mutagenic. There is reason to expect the quantal type of biological response that is characteristic of mutagenesis is associated with a linear non-threshold dose-response relationship. Indeed, there is substantial evidence from mutagenesis studies with both ionizing radiation and a wide variety of chemicals that this type of dose-response model is the appropriate one to use. This is particularly true at the lower end of the dose-response curve; at higher doses, there can be an upward curvature probably reflecting the effects of multistage processes on the mutagenic response. The linear non-threshold dose-response relationship is also consistent with the relatively few epidemiological studies of cancer responses to specific agents that contain enough information to make the evaluation possible (e.g., radiation induced leukemia, breast and thyroid cancer, skin cancer induced by arsenic in drinking water, liver cancer induced by aflatoxin in the diet). There is also some evidence from animal experiments that is consistent with the linear non-threshold model (e.g., liver tumors induced in mice by 2-acetylaminofluorene in the large scale $ED_{01}$ study at the National Center for Toxicological Research and the initiation stage of the two-stage carcinogenesis model in rat liver and mouse skin).

Because it has the best, albeit limited, scientific basis of any of the current mathematical extrapolation models, the linear non-threshold model has been adopted as the primary basis for risk extrapolation to low levels of the dose-response relationship. The risk estimates made with this model should be regarded as conservative, representing the most plausible upper limit for the risk, i.e., the true risk is not likely to be higher than the estimate, but it could be smaller.

The mathematical formulation chosen to describe the linear, non-threshold dose-response relationship at low doses is the improved multistage model developed by Dr. K. Crump. This model employs enough arbitrary constants to be able to fit almost any monotonically increasing dose-response data and it incorporates a procedure for estimating the largest possible linear slope (in the 95% confidence limit sense) at low extrapolated doses that is consistent with the data at all dose levels of the experiment.

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## B. Description of the Extrapolation Model

Let P(d) represent the lifetime risk (probability) of cancer at dose d. The multistage model has the form

$$P(d) = 1 - \exp\left[-(q_0 + q_1 d + q_2 d^2 + \ldots + q_k d^k)\right] .$$

where

$$q_i \geq 0, \; i = 0, 1, 2, \ldots, k$$

Equivalently,

$$A(d) = 1 - \exp\left[-(q_1 d + q_2 d^2 + \ldots + q_k d^k)\right]$$

where

$$A(d) = \frac{P(d) - P(0)}{1 - P(0)},$$

is the extra risk over background rate at dose d.

The point estimate of the coefficients $q_i$, $i = 0, 1, 2, \ldots, k$ and consequently the extra risk function A(d) at any given dose d is calculated by maximizing the likelihood function of the data.

The point estimate and the 95% upper confidence limit of the extra risk A(d) are calculated by using the computer program GLOBAL 79 developed by Crump and Watson (1979). The calculation proceeds as follows: Let $L_0$ be the maximum value of the log-liklihood function. The 95% upper confidence limit for the extra risk A(d) has the form

$$A_u(d) = 1 - \exp\left[-(q_1^* d + \hat{q}_2 d^2 + \ldots + \hat{q}_k d^k)\right]$$

where $q_1^*$ is calculated by increasing $q_1$ to a value $q_1^*$ such that when the log-liklihood is remaximized subject to this fixed value $q_1^*$ for the linear coefficient, the resulting maximum value of the log-likelihood $L_1$ satisfies the equation

$$2\,(L_0 - L_1) = 2.70554$$

where 2.70554 is the cumulative 90% point of the chi-square distribution with one degree of freedom, which corresponds to a 95% upper limit (one-sided). The quantities $\hat{q}_2$, $\hat{q}_3$, ..., $\hat{q}_k$ are the maximum likelihood estimates of the other coefficients given $q_1$ equal to $q_1{}^*$. This approach of computing the upper confidence limit for the extra risk A(d) is an improvement on the Crump et al. (1977) model. At low doses, the exponent $g(d) = q_1{}^*d + \hat{q}_2d^2 + \ldots + \hat{q}_kd^k$ is dominated by the linear term $q_1{}^*d$ and hence

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$$A_u(d) = 1 - \exp(-\ q_1{}^*d) \approx q_1{}^*d$$

Therefore, the upper confidence limit for the extra risk A(d) at low doses is always linear. This is conceptually consistent with the linear non-threshold concept discussed earlier. The slope $q_1{}^*$ is a measure of the potency of the chemical in inducing cancer at low doses.

In fitting the dose-response model, the number of terms in the polynomial g(d), is chosen equal to (h-1) where h is the number of dose groups in the experiment including the control group.

Whenever the multistage model does not fit the data sufficiently well, data at the highest dose is deleted and the model is refitted to the rest of the data. This is continued until an acceptable fit to the data is obtained. To determine whether or not a fit is acceptable, the chi-square statistic

$$X^2 = \sum_{i=1}^{h} \frac{(X_i - N_iP_i)^2}{N_iP_i\ (1 - P_i)}$$

is calculated where $N_i$ is the number of animals in the $i^{th}$ dose group, $X_i$ is the number of animals in the $i^{th}$ dose group with a tumor response, $P_i$ is the probability of a response in the $i^{th}$ dose group estimated by fitting the multistage model to the data, and h is the number of remaining groups. The fit is determined to be unacceptable whenever $X^2$ is larger than the cumulative 99%

point of the chi-square distribution with f degree of freedom, where f equals the number of dose groups minus the number of non-zero multistage coefficients.

## SELECTION AND FORM OF DATA USED TO ESTIMATE PARAMETERS IN THE EXTRAPOLATION MODEL

For some chemicals, several studies in different animal species, strains, and sexes each run at several doses and different routes of exposure are available. A choice must be made of which of the data sets from several studies to use in the model. It is also necessary to correct for metabolism differences between species and absorption factors via different routes of administration. The procedures used in evaluating these data are consistent with the approach of making a maximum-likely risk estimate. They are listed below.

1. The tumor incidence data are separated according to organ sites or tumor types. The set of data (i.e., dose and tumor incidence) used in the model is the set where the incidence is statistically significantly higher than the control for at least one test dose level and/or where the tumor incidence rate shows a statistically significant trend with respect to dose level. The data set which gives the highest estimate of the lifetime carcinogenic risk $q_1^*$ is selected in most cases. However, efforts are made to exclude data sets which produce spuriously high risk estimates because of a small number of animals. That is, if two sets of data show a similar dose-response relationship and one has a very small sample size, the set of data which has larger sample size is selected for calculating the carcinogenic potency.

2. If there are two or more data sets of comparable size which are identical with respect to species, strain, sex, and tumor sites, the geometric mean of the exponent g(d), estimated from each of these data sets and evaluated at a specific dose d, is used for risk assessment. The geometric mean of numbers

$A_1, A_2, \ldots, A_m$ is defined as

$$(A_1 \times A_2 \times \ldots \times A_m)^{1/m}$$

3. If two or more significant tumor sites are observed in the same study and if the data are available to us, the number of animals with at least one of the specific tumor sites under consideration is used as incidence data in the model.

4. Following the suggestion of Mantel and Schneiderman (1977) we assume that mg/surface area/day is an equivalent dose between species. Since to a close approximation the surface area is proportional to the 2/3 rds power of the weight as would be the case for a perfect sphere, the exposure in mg/day per 2/3 rds power of the weight is also considered to be an equivalent exposure. In an animal experiment this equivalent dose is computed in the following manner.

Let

$L_e$ = duration of experiment

$l_e$ = duration of exposure

$m$ = average dose per day in mg during administration of the agent (i.e., during $l_e$)

$W$ = average weight of the experimental animal

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Then, the lifetime average exposure is

$$d = \frac{l_e \times m}{L_e \times W^{2/3}}$$

Often exposures are not given in units of mg/day and it becomes necessary to convert the given exposures into mg/day. For example in most feeding studies exposure is in terms of ppm in the diet. In this case the exposure in mg/day is

$$m = ppm \times F \times r$$

where ppm is parts per million in the diet of the carcinogenic agent and F is the weight of the food consumed per day in kgms and r is the absorption fraction. In the absence of any data to the contrary r is assumed to be equal to one. For a uniform diet the weight of the food consumed is proportional to the calories required which in turn is proportional to the surface area or 2/3rds power of the weight, so that

$$m \propto ppm \times W^{2/3} \times r \text{ or}$$

$$\frac{m}{rW^{2/3}} \propto ppm$$

As a result, ppm in the diet is often assumed to be an equivalent exposure between species. However, we feel that this is not justified since the calories/kg of food is very different in the diet of man compared to laboratory animals primarily due to moisture content differences. Instead we use an empirically derived food factor f = F/W which is the fraction of a species body weight that is consumed per day as food. We use the rates given below.

| Species | W | f |
|---|---|---|
| Man | 70 | 0.028 |
| Rat | 0.35 | 0.05 |
| Mice | 0.03 | 0.13 |

Thus, when the exposure is given as a certain dietary concentration in ppm the exposure in $mg/W^{2/3}$ is

$$\frac{m}{r \times W^{2/3}} = \frac{ppm \times F}{W^{2/3}} = \frac{ppm \times fxW}{W^{2/3}} = ppm \times f \times W^{1/3}$$

When exposure is given in terms of mg/kg/day = m/Wr = s the conversion is simply

$$\frac{m}{rW^{2/3}} = s \times W^{1/3}$$

When exposure is via inhalation, the calculation of dose can be considered for two cases where 1) the carcinogenic agent is either a completely water soluble gas or an aerosal and is absorbed proportionally to the amount of air breathed in, and 2) where the carcinogen is a poorly water soluble gas which reaches an equilibrium between the air breathed and the body compartments. After equilibrium is reached, the rate of absorption of these agents is expected to be proportional to the metabolic rate, which in turn is proportional to the rate of oxygen consumption, which in turn is a function of surface area.

Case 1

Agents that are in the form of particulate matter or virtually completely absorbed gases such as $SO_2$ can reasonably be expected to be absorbed proportional to the breathing rate. In this case the exposure in mg/day may be expressed as

$$m = I \times \quad \times r$$

where

$I$ = inhalation rate per day in $m^3$
$v$ = $mg/m^3$ of the agent in air
$r$ = the absorption fraction

The inhalation rates, I, for various species can be calculated from the observations (FASEB 1974) that 25 gm mice breathe 34.5 liters/day and 113 gm rats breathe 105 liters/day. For mice and rats of other weights, W (in kilograms), the surface area proportionality can be used to find breathing rates in $m^3$/day as follows:

$$\text{For mice, } I = 0.0345\,(W/0.025)^{2/3}\ m^3/\text{day}$$

$$\text{For rats, } I = 0.105\,(W/0.113)^{2/3}\ m^3/\text{day}$$

For humans, the values of 20 $m^3$/day† is adopted as a standard breathing rate (ICRP 1977).

The equivalent exposure in $mg/W^{2/3}$ for these agents can be derived from the air intake data in way analogous to the food intake data.

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†From "Recommendation of the International Commission on Radiological Protection", page 9, the average breathing rate is $10^7$ $cm^3$ per 3 hour work day and $2 \times 10^7$ $cm^3$ in 24 hours.

The empirical factors for the air intake per kg per day, $i = I/W$ based upon the previous stated relationships are tabulated below

| Species | W | i = I/W |
|---|---|---|
| Man | 70 | 0.29 |
| Rat | 0.35 | 0.64 |
| Mice | 0.03 | 1.3 |

Therefore, for particulates or completely absorbed gases, the equivalent exposure in mg/$W^{2/3}$ is

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$$\frac{m}{W^{2/3}} = \frac{Ivr}{W^{2/3}} = \frac{iWvr}{W^{2/3}} = iW^{1/3}\,vr$$

In the absence of experimental information or a sound theoretical argument to the contrary, the fraction absorbed, $r$, is assumed to be the same for all species.

Case 2

The dose in mg/day of partially soluble vapors is proportional to the $O_2$ consumption which in turn is proportional to $W^{2/3}$ and also proportional to the solubility of the gas in body fluids, which can be expressed as an absorption coefficiennt $r$ for the gas. Therefore, expressing the $O_2$ consumption as $O_2 = kW^{2/3}$ where k is a cconstant independent of species, it follows that

$$m = k\,W^{2/3} \times v \times r$$

or

$$d = \frac{m}{W^{2/3}} = kvr$$

As with Case 1, in the absense of experimental information or a sound theoretical argument to the contrary, the absorption fraction, $r$, is assumed to be the same for all species. Therefore, for these substances a certain concentration in ppm or ug/$m^3$ in experimental animals is equivalent to the same concentration in humans. This is supported by the observation that the minimum alveolar concentration that is necessary to produce a given "stage" of anesthesia is similar in man and animals (Dripps, et al. 1975). When the animals were exposed via the oral route and human exposure is via inhalation or vice-versa, the assumption is made, unless there is pharmacokenetic evidence to the contrary, that absorption is equal by either exposure route.

5. If the duration of experiment (Le) is less than the natural lifespan of the test animal (L), the slope $q_1^*$ or more generally the exponent g(d) is increased by multiplying a factor $(L/L_e)^3$. We assume that if the average dose, D, is continued, the age specific rate of cancer will continue to increase as a constant function of the background rate. The age specific rates for humans increases at least by the 2nd power of the age and often by a considerably higher power as demonstrated by Doll (1971). Thus, we would expect the cumulative tumor rate to increase by at least the 3rd power of age. Using this fact we assume that the slope $q_1^*$ or more generally the exponent g(d), would also increase by at least the 3rd power of age. As a result, if the slope $q_1^*$ [or g(d)] is calculated at age Le, we would expect that if the experiment had been continued for the full lifespan, L, at the given average exposure, the slope $q_1^*$ [or g(d)] would have been increased by at least $(L/Le)^3$.

This adjustment is conceptually consistent to the proportional hazard model proposed by Cox (1972) and the time-to-tumor model considered by Crump et al. (1979) where the probability of cancer at age t and dose d is given by

$$P(d,t) = 1 - \exp[-f(t) \times g(d)]$$

This more refined approach would be used in the calculations of unit risk when the data are available.

## CALCULATION OF OF THE UNIT RISK

The risk associate with d $mg/kg^{2/3}/day$ as noted previously is

$$A_u(d) = 1-\exp[-(q_1^* d + \hat{q}_2 d^2 + \ldots + \hat{q}_k d^k)]$$

A "unit risk" in units X is simply the risk corresponding to an exposure of $X = 1$. To estimate this value we simply find the number of $mg/kg^{2/3}/day$ corresponding to one unit of X and substitute this value into the above relationship. Thus, for example if X is in units of $ug/m^3$ in the air we have that for

$$\text{case (1)} \quad d = 0.29 \times 70^{1/3} \times 10^{-3} = 1.195 \times 10^{-3}$$

and for case (2) $d = 1$ when $ug/m^3$ is unit used to compute parameters in animal experiment.

If exposures are given in terms of ppm in air we may simply use the fact that

$$1 \text{ ppm} = 1.2 \times \frac{\text{molecular weight (gas)}}{\text{molecular weight (air)}} \text{ mg/m}^3$$

Note, an equivalent method of calculating unit risk would be to use mg/kg for the animal exposures and then increase the jth polynomial coefficient by an amount

$$(W_h/W_a)^{j/3} \qquad j = 1,2,\ldots,k$$

and use mg/kg equivalents for the unit risk values.

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## ESTIMATION OF UNIT RISK BASED ON HUMAN DATA

If human epidemiology studies and sufficiently valid exposure information are available for the compound, they are always used in some way. If they show a carcinogenic effect, the data are analyzed to give an estimate of the linear dependence of cancer rates on lifetime average dose, which is equivalent to the factor $B_H$. If they show no carcinogenic effect when positive animal evidence is available, then it is assumed that a risk does exist but it is smaller than could have been observed in the epidemiology study, and an upper limit of the cancer incidence is calculated assuming hypothetically that the true incidence is just below the level of detection in the cohort studied, which is determined largely by the cohort size. Whenever possible, human data are used in preference to animal bioassay data.

In human studies, the response is measured in terms of the relative risk of the exposed cohort of individuals compared to the control group. In the analysis of this data it is assumed that the excess risk, or relative risk minus one, $R(X_1) - 1$, is proportional to the lifetime average exposure, $X_1$, and that it is the same for all ages. It follows that the lifetime risk in the general population exposed to a lifetime average concentration $X_2$, $P(X_2)$, is equal to $[R(X_1) - 1]X_2/X_1$ multiplied by the lifetime risk at that site in the general population. The unit risk estimate is the value of P when $X_2$ is 1 $ug/m^3$. Except for an unusually well documented human study, the confidence limit for the excess risk P is not calculated, due to the difficulty of accounting for the uncertainty inherited in the data (exposure and cancer response).

## INTERPRETATION OF UNIT RISK

The unit risk estimate is a rough indication of the relative potency of a given agent compared with other carcinogens. The comparative potency of different agents is more reliable when the comparison is based on studies in the same test species, strain, and sex and by the same route of exposure, preferably by inhalation.

For several reasons the unit risk estimate is only an approximate indication of the absolute risk in populations exposed to known air concentrations. First, there are important species differences in uptake, metabolism, and organ distribution of carcinogens, as well as species differences in target site susceptibility, immunological responses, hormone function, dietary factors, and disease. Secondly, the concept of equivalent doses for humans compared to animals on a mg/surface area basis is virtually without experimental verification regarding carcinogenic response. Finally, human populations are variable with respect to genetic constitution and diet, living environment, activity patterns, and other cultural factors.

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# Division 9

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VI
1201 ELM STREET
DALLAS, TEXAS 75270

Mr. William B. Philipbar, Jr., President
Rollins Environmental Services, Inc.
One Rollins Plaza
Wilmington, Delaware 19899

Dear Mr. Philipbar:

Based on the results of test burns conducted at your facility in October 1979 and August 1980, I hereby grant approval to you to incinerate PCBs at the Rollins Environmental Services facility at Deer Park, Texas, under the authority of Section 6 of the Toxic Substances Control Act. The approval is subject to the conditions specified in the attachment to this letter.

Violation of any condition included as part of the approval will subject Rollins to enforcement action under the appropriate statute and/or termination of the approval. Furthermore, this approval may be withdrawn or further conditions may be added anytime I feel that the operation of the incinerator presents an unreasonable risk of injury to health or the environment from PCB incineration. This approval shall be effective on March 4, 1981.

If you have any questions, please contact me.

Sincerely,

Adlene Harrison

Adlene Harrison
Regional Administrator

cc: Governor Bill Clements
State of Texas

Mr. Bill Stuart, Director
Texas Air Control Board

Mr. Harvey Davis, Director
Texas Department of Water Resources

# Condition for Incineration of Liquid PCBs
# at Rollins Environmental Services
# of Deer Park, Texas

1. At all times during PCB incineration the incinerator shall meet the requirements specified in 40 CFR 761.40(a).

2. The PCB feed rate shall not exceed an average of 2439 lbs/hr calculated over the actual period of incineration of the PCB material.

3. The $CO_2$ level shall be measured every 24 hours during PCB incineration.

4. The flow of PCBs to the incinerator shall stop automatically under any of the following conditions:

   a. the temperature drops below 1150°C at the exit end of the combustion zone,

   b. the CO level shall not exceed 10 times the $CO_2$ level, and in any event shall not exceed 100 ppm (calibrate monitors every 24 hours during PCB incineration by zero and span gas), or

   c. the $O_2$ drops below 3% (monitors shall be calibrated every 24 hours by zero and span gas).

5. The water scrubber shall at least achieve 99% HCl removal efficiency, and shall not emit greater than 40 lbs/hr HCl. Chorine input shall be determined by the appropriate ASTM method. Stack gases shall be sampled using impingers containing NaOH, and analyzed for chloride using the Argentimetric method as specified in Standard Methods for Water and Waste Water, current edition.

6. Total particulate emission shall not exceed State emission limit for particulate emissions during PCB incineration.

7. All records and data shall be maintained in accordance with 40 CFR 761.45(b), (c), and (f).

8. All PCB storage facilities shall comply with 40 CFR 761.42. These requirements include implementation of an SPCC Plan for PCB storage and feed tanks as described under 40 CFR 761.42(7)(ii).

9. Any PCB container used for PCB transport, storage, or disposal shall not be used for any other purpose unless decontamination of the container complies with 40 CFR 761.43. All decontamination wash fluids shall be incinerated.

10. All PCB articles, equipment, and containers shall be properly marked according to 40 CFR 761.44.

11. Rollins shall comply with NPDES requirements for PCB discharges.

12. Rollins shall comply with all State and local permits for the incineration of wastes during PCB incineration.

13. Rollins personnel safety requirements and procedures for PCB handling, storage, transport, and disposal shall comply with OSHA requirements.

14. Any violation or noncompliance with the conditions referenced herein may result in suspension or revocation of the final approval for incineration of PCBs.

15. Rollins must comply with 40 CFR Part 265 and Part 122 of the May 19, 1980, Hazardous Waste Regulations ("Interim Status Standards" and "RCRA Hazardous Waste Permit Regulations").

16. EPA may require annual testing or monitoring of the facility for PCBs, HCl, particulates and up to 3 organics identified by EPA. Written reports discussing the results of the testing or monitoring shall be submitted to EPA within 180 days. Any modification to the approved facility which may result in increased or changes in types of emissions may require additional testing or monitoring.

17. Rollins must maintain a negative draft sufficient to prevent fugitive emissions from the kiln or after burners.

18. Should an Air Stagnation Advisory be issued which includes Harris County, Texas the facility shall upon notification by EPA or the State cease incineration of PCBs until an "all clear" is issued in accordance with the Texas SIP.

19. Rollins will through contractural agreement, hire a private engineering company to conduct regular monitoring of the Rollins facility. The selection of the private engineering company must be approved by EPA, Region 6. The contract scope of work shall at least include the scope of work prepared by EPA, Region 6 in order to ensure that all monitoring as a condition of the approval is included. The private enginering company will monitor the Rollins facility and will report the monitoring results to EPA. The contract scope of work and reporting will be in accordance with the attached Scope of Work for Monitoring. This condition must be satisfied prior to incineration of PCBs under this approval.

20. The conditions of this authorization are severable, and if any provision of this authorization, or any applications of any provision, is held invalid, the remainder of this authorization shall not be affected thereby.

# Scope of Work for Monitoring the Rollins Environmental Services Facility
# Deer Park, Texas

## I. Background

The purpose of this scope of work is to ensure that the incineration of PCBs is continuously accomplished consistent with the conditions set forth in the letter of approval dated __________ from EPA, Region 6 regarding the incineration of PCBs at Rollins Environmental Services in Deer Park, Texas. Rollins will contract with and compensate a registered professional engineer who is mutually acceptable to both Rollins and EPA. The contractor will monitor Rollin's operations with regard to the conditions specified in the above referenced letter. The monitoring will be conducted by the contractor at random intervals, on an unannounced basis. Rollins will provide the contractor immediate access at any time to its entire facility. The monitoring under the proposed contract will be consistent with the principles set forth in EPA's Toxic Substance Control Act (TSCA) PCB Monitoring and Disposal Regulation Interim Inspection Guidance regarding TSCA inspections for the incineration of PCBs. This contractual arrangement is not and should not be construed as a substitute for periodic TSCA inspections conducted by EPA personnel or inspections conducted by EPA's authorized representatives.

Prior to awarding the contract, Rollins has agreed to provide EPA an opportunity to review and comment on the terms to be included therein and, if necessary, EPA may require Rollins to modify the terms of the contract to ensure consistency with the January ____, 1981, letter of approval mentioned above.

## II. Specific Requirements of Monitoring

The monitoring shall include at a minimum:

1. A general monitoring of the incinerator including the PCB shredder area, rotary kiln, the condition and maintenance of the main combustion chamber area, scrubber and stack (including plume opacity readings). The contractor will report on the overall operating condition of the incinerator (eg., instrument conditions, scrubber performance, stack opacity, evidence of PCB spillage, negative draft maintained to prevent fugitive emissions).

2. The contractor shall examine and record the feed rate records for the past 48 hours of PCB incineration and determine the actual feed rate of PCBs fed to the incinerator. This item will include copies (if any) of PCB analytical results retained by Rollins of all PCB materials fed to the incinerator during the previous 48 hours.

3. The contractor shall examine the record and $CO_2$ level in the combustion gases upstream of the scrubber, the PCB cutoff level set for the CO, $O_2$, and temperature instruments, and shall observe that the cutoff mechanisms are operable. Also, the contractor shall check the continuous $O_2$ and CO monitors with zero and span gas to ensure proper calibration of the monitors. The contractor shall also check recorders for CO, $O_2$, and temperature.

4. The contractor shall determine if Rollins ceased burning PCBs upon an issuance of an Air Stagnation Advisory by NOAA for the surrounding area since the last monitoring activity.

5. Upon completion of the inspection, the contractor will call the Project Officer (Region 6 Office) as soon as possible to give a verbal report on the monitoring.

6. The contractor shall monitor the incinerator 5 times per month at variable intervals and at variable times. During each month the monitoring visits will take place at least one time during each shift.

7. A full written report shall be prepared every 90 days, and submitted to the Region 6 Office within 30 days of the expiration of each 90 day reporting period. The reporting format shall follow the format as shown in Attachment 1.

## III. Qualifications of the Contractor

The contractor shall be a Registered Professional Engineer, knowledgable of combustion theory and incineration. The contractor shall also be certified in evaluating plume opacity in accordance with EPA method 9 (40 CFR Part 60).

## ATTACHMENT 1

### Rollins Environmental Services Reporting Format

I. Statement of Date and Time of monitoring and person conducting monitoring.

II. General summary of observations during each monitoring date highlighting compliance and/or non-compliance to the approval conditions.

III. Detailed summary of comparison of the operating conditions and limitations specified in the approval conditions. This summary shall include appropriate copies of records and strip chart data from CO, $O_2$ and temperature instruments.

IV. Summary of observations of areas where PCBs or PCB items were transported, handled, processed, or decontaminated for evidence of PCB contamination. The contractor will record facility procedures that assure incineration of all PCBs. This section shall include observations of the disposition of used PCB containers, articles, and equipment.

V. Summary of incinerator records and combustion products monitoring records. Record whether $O_2$, CO, $CO_2$, and temperature were monitored at all times during the PCB incineration period. This section shall include what PCB cutoff levels were in use for CO during the previous 48 hours of PCB incineration, and a summary of whether PCB cutoff mechanisms were operable and if CO and $O_2$ continuous monitors were calibrated according to requirements. Obtain feed rate data and determine if PCB feed rate during previous 48 hours of PCB incineration from each monitoring date was within the required limit.

VI. A summary of observation of the water scrubber, scrubber lagoon, and stack plume opacity. State the condition of the scrubber lagoon's freeboard, and the operability of pumps and compressors during the monitoring.

6 01

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION VI
1201 ELM STREET
DALLAS, TEXAS 75270

Mr. Melvyn Bell, President
Energy Systems Company
P. O. Box 1975
El Dorado, Arkansas 71730

Dear Mr. Bell:

Based on the results of test burns conducted at your facility in October 1979 and August 1980, I hereby grant approval to you to incinerate PCBs at the ENSCO facility at El Dorado, Arkansas, under the authority of Section 6 of the Toxic Substances Control Act. The approval is subject to the conditions specified in the enclosure to this letter.

Violation of any condition included as part of the approval will subject ENSCO to enforcement action under the appropriate statute and/or termination of the approval. Furthermore, this approval may be withdrawn or further conditions may be added at any time I feel that the operation of the incinerator presents an unreasonable risk of injury to health or the environment from PCB incineration. This approval shall be effective on March 12, 1981.

If you have any questions, please contact me.

Sincerely,

/s/ Adlene Harrison

Adlene Harrison
Regional Administrator

Enclosure

cc: Governor Frank D. White
State of Arkansas

Jarrell E. Southall, Director
Arkansas Department of Pollution Control
and Ecology

### Condition for Incineration of Liquid and Solid PCBs
### at Energy Systems Company (ENSCO)
### El Dorado, Arkansas

1. At all times during PCB incineration, the incinerator shall meet the requirements specified in 40 CFR 761.40(a).

2. The PCB feed rate shall not exceed an average of 289 kg/hr calculated over the actual period of incineration of the PCB material.

3. The $CO_2$ level shall be measured in the "hot duct" every 24 hours during PCB incineration.

4. The flow of PCBs to the incinerator shall stop automatically under any of the following conditions:

   a. the temperature drops below 1150°C at the exit end of the combustion zone,

   b. the CO level shall not exceed 10 times the $CO_2$ level, and in any event shall not exceed 100 ppm (calibrate monitors every 3 hrs. during PCB incineration by zero and span gas), or

   c. the $O_2$ drops below 4% (calibrate monitor every 24 hrs. with zero and span gas).

5. The water scrubber shall at least achieve 99% HCl removal efficiency, and shall not emit greater that 37 lbs/hr HCl. Chlorine input will be determined by the appropriate ASTM method. Stack gases shall be sampled using impinger containing NaOH, and analyzed for chloride using the Argentimetric method as specified in Standard Methods for Examination of Water and Waste Water, current edition.

6. Total particulate emissions shall not exceed State emission limit for particulate emissions.

7. All records and data shall be maintained in accordance with 40 CFR 761.45(b), (c), and (f).

8. All PCB storage facilities shall comply with 40 CFR 761.42. These requirements include implementation of an SPCC Plan for PCB storage and feed tanks as described under 40 CFR 761.42(7)(ii).

9. Any PCB container used for PCB transport, storage, or disposal shall not be used for any other purpose unless decontamination of the container complies with 40 CFR 761.43. All decontamination wash fluids shall be incinerated.

10. All PCB articles, equipment, and containers shall be properly marked according to 40 CFR 761.44.

11. ENSCO shall comply with NPDES requirements for PCB discharges.

12. ENSCO shall comply with all State and local permits for the incineration of wastes during PCB incineration.

13. ENSCO personnel safety requirements and procedures for PCB handling, storage, transport, and disposal shall comply with OSHA requirements.

14. Any violation or noncompliance with the conditions referenced herein may result in suspension or revocation of the final approval for incineration of PCBs.

15. ENSCO must comply with 40 CFR Part 265 and Part 122 of the May 19, 1980, Hazardous Waste Regulations ("Interim Status Standards" and "RCRA Hazardous Waste Permit Regulations") and any subsequent amendments.

16. EPA may require annual testing or monitoring of the facility for PCBs, HCl, particulates and up to 3 organics identified by EPA. Written reports discussing the results of the testing or monitoring shall be submitted to EPA within 180 days. Any modification to the approved facility which may result in increased or changes in types of emissions may require additional testing or monitoring.

17. ENSCO must maintain a negative draft sufficient to prevent fugitive emissions from the kiln or after burners.

18. Kiln ash containing less than 50 ppm PCBs may be placed in a permitted landfill; ash containing PCB concentrations greater than 50 ppm will require the ash to be recycled through the kiln, or disposed in an approved PCB landfill.

19. Should an Air Stagnation Advisory be issued which includes Union County, Arkansas, the facility shall upon notification by EPA or the State cease incineration of PCBs until an "all clear" is issued in accordance with the Arkansas SIP.

20. ENSCO will through contractual agreement, hire a private engineering company to conduct regular monitoring of the ENSCO facility. The selection of the private engineering company must be approved by EPA, Region 6. The contract scope of work will be prepared by EPA, Region 6. The private engineering company will monitor the ENSCO facility and will report the monitoring results to EPA. The contract scope of work and reporting will be in accordance with the attached Scope of Work for Monitoring . This condition must be satisfied prior to incineration of PCBs under this approval.

21. The conditions of this authorization are severable, and if any provision of this authorization, or any applications of any provision, is held invalid, the remainder of this authorization shall not be affected thereby.

22. Conditions 6 and 20 must be satisfied prior to incineration of PCBs under this approval.

# Scope of Work for Monitoring the ENSCO Facility
El Dorado, Arkansas

## I. Background

The purpose of this scope of work is to ensure that the incineration of PCBs is continuously accomplished consistent with the conditions set forth in the letter of approval dated January 26, 1981, from EPA, Region 6 regarding the incineration of PCBs at Energy System Company (ENSCO) in El Dorado, Arkansas. ENSCO will contract with and compensate a registered professional engineer who is mutually acceptable to both ENSCO and EPA. The contractor will monitor ENSCO's operations with regard to the conditions specified in the above referenced letter. The monitoring will be conducted by the contractor at random intervals, on an unannounced basis. ENSCO will provide the contractor immediate access at any time to its entire facility. The monitoring under the proposed contract will be consistent with the principles set forth in EPA's Toxic Substance Control Act (TSCA) PCB Monitoring and Disposal Regulation Interim Inspection Guidance regarding TSCA inspections for the incineration of PCBs. This contractual arrangement is not and should not be construed as a substitute for periodic TSCA inspections conducted by EPA personnel or inspections conducted by EPA's authorized representatives.

Prior to awarding the contract, ENSCO has agreed to provide EPA an opportunity to review and comment on the terms to be included therein and, if necessary, EPA may require ENSCO to modify the terms of the contract to ensure consistency with the January 26, 1981, letter of approval mentioned above.

## II. Specific Requirements of Monitoring

The monitoring shall include at a minimum:

1. A general monitoring of the incinerator including the PCB shredder area, rotary kiln, the condition and maintenance of the main combustion chamber area, scrubber and stack (including plume opacity readings). The contractor will report on the overall operating condition of the incinerator (eg., instrument conditions, scrubber performance, stack opacity, evidence of PCB spillage, negative draft maintained to prevent fugitive emissions, disposition of kiln ash).

2. The contractor shall examine and record the feed rate records for the past 48 hours of PCB incineration and determine the actual feed rate of PCBs fed to the incinerator. This item will include copies (if any) of PCB analytical results retained by ENSCO of all PCB materials fed to the incinerator during the previous 48 hours.

3. The contractor shall examine the record and $CO_2$ level in the combustion gases upstream of the scrubber, the PCB cutoff level set for the CO, $O_2$, and temperature instruments, and shall observe that the cutoff mechanisms are operable. Also, the contractor shall check the continuous $O_2$ and CO monitors with zero and span gas to ensure proper calibration of the monitors. The contractor shall also check recorders for CO, $O_2$, and temperature.

4. The contractor shall determine if ENSCO ceased burning PCBs upon an issuance of an Air Stagnation Advisory by NOAA for the surrounding area since the last monitoring activity.

5. Upon completion of the inspection, the contractor will call the Project Officer (Region 6 Office) as soon as possible to give a verbal report on the monitoring.

6. The contractor shall monitor the incinerator 5 times per month at variable intervals and at variable times. During each month the monitoring visits will take place at least one time during each shift (the operation of the incinerator entails 3 shifts per day).

7. A full written report shall be prepared every 90 days, and submitted to the Region 6 Office within 30 days of the expiration of each 90 day reporting period. The reporting format shall follow the format as shown in Attachment 1.

## III. Qualifications of the Contractor

The contractor shall be a Registered Professional Engineer, knowledgeable of combustion theory and incineration. The contractor shall also be certified in evaluating plume opacity in accordance with EPA method 9 (40 CFR Part 60).

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## ATTACHMENT 1

### ENSCO Reporting Format

I. Statement of Date and Time of monitoring and person conducting monitoring.

II. General summary of observations during each monitoring date highlighting compliance and/or non-compliance to the approval conditions.

III. Detailed summary of comparison of the operating conditions and limitations specified in the approval conditions. This summary shall include appropriate copies of records and strip chart data from CO, $O_2$ and temperature instruments.

IV. Summary of observations of areas where PCBs or PCB items were transported, handled, processed, or decontaminated for evidence of PCB contamination. The contractor will record facility procedures that assure incineration of all PCBs. This section shall include observations of the disposition of used PCB containers, articles, and equipment.

V. Summary of incinerator records and combustion products monitoring records. Record whether $O_2$, CO, $CO_2$, and temperature were monitored at all times during the PCB incineration period. This section shall include what PCB cutoff levels were in use for CO during the previous 48 hours of PCB incineration, and a summary of whether PCB cutoff mechanisms were operable and if CO and $O_2$ continuous monitors were calibrated according to requirements. Obtain feed rate data and determine if PCB feed rate during previous 48 hours of PCB incineration from each monitoring date was within the required limit.

VI. A summary of observation of the water scrubber, scrubber lagoon, and stack plume opacity. State the condition of the scrubber lagoon's freeboard, and the operability of pumps and compressors during the monitoring.